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APPLIED MECHANICS REVIEWS

VOL. 9, NO. 11 MARTIN GOLAND *Editor* NOVEMBER 1956

THE NEW LOOK IN LIBRARY SCIENCE

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INTRODUCTION

FIVE billion dollars, it is estimated, are being spent annually in the United States for scientific research and technical developments. Industrial organizations today accept the search for knowledge and its successful application as decisively important areas for competitive activity. Our government—regardless of political party—realizes that, in war or peace, our position in the world is decisively dependent on the achievements of our scientists and engineers. There is widespread concern lest a shortage of scientific and technical personnel may result in our failing to keep pace with our Soviet competitors whose efforts in the realm of science and technology are often large scale—sometimes even spectacular (1).

Eventual success in research is no longer enough. Efficiency in research has become a necessity. Powerful new tools for raising the level of research efficiency are being provided by new developments in the field of library science.

THE ROLE OF LIBRARY SCIENCE

The importance of efficient library techniques derives from the very nature of research. Neither pure nor applied research can be equated with the mere performance of experiments. Applied research is directed to the solution of practical problems such as designing or producing a device having certain functions or capabilities. Pure research is directed to acquiring better understanding of the laws of nature. Neither practical nor theoretical goals can be attained efficiently without careful thought both in designing experiments and in evaluating and correlating experimental results. The basis for such thought must, in both cases, be previously acquired knowledge. Failure to apply available knowledge in planning, conducting, evaluating, and exploiting research can result in severe impairment of returns from money budgeted for research. Inadvertent repetition of previously performed investigations constitutes a particularly glaring type of misdirected effort and its avoidance justifies considerable effort. Even more costly, in the long run, is consistent low efficiency in the use of previously recorded knowledge to ensure that research is so planned that a maximum of useful results are achieved at a minimum cost in time, effort, and money. Providing recorded knowledge, when needed, in an efficient and purposeful manner is the task of library science.

As a preliminary to more detailed review it should be pointed out that wide diversity among various information collections and information requirements finds its counterpart in wide diversity of library methods and techniques. An information collection may range from a private collection of reprints to a full-scale library of many thousand volumes. Similarly, information requirements may range from the need to know some individual fact to the necessity of a comprehensive correlation of facts bearing on a broad problem, such as the prevention of air pollution. In managing collections of varying size and complexity and in meeting various information requirements, different methods and techniques can be expected to provide optimum advantages. The evaluation of requirements in a given situation and adaptation of the most advantageous methods and techniques often present complex problems. Frequently it turns out that a coordinated combination of methods —both old and new—is required to provide the maximum margin of benefits over costs. As will be evident from subsequent discussion, various methods can be altered and adapted to fit different conditions. It is also possible, in establishing a working system, to anticipate the possibility of changing circumstances imposing new requirements, whose satisfaction may require changes in the original system. Such anticipation of future requirements is likely to be particularly effective in avoiding excessive future costs when making adjustments and changeovers.

In establishing and operating an information system, a number of functional operations must be performed. The three basic functions are (1) storage of publications, reports, and similar records; (2) identification of those items that are of

probable pertinent interest to a given problem or situation; (3) providing from storage items that have been so identified. Other operations may supplement these, such as photographic or other forms of reproduction of documents, maintaining security regulations, etc. The three basic operations, namely storage, identification, and withdrawal from storage, differ considerably in the nature of the problems encountered. Storage and withdrawal from storage involve almost exclusively engineering considerations and these will not be considered further in this paper. Identification of items of pertinent interest, on the other hand, involves difficult intellectual problems that have been the center of attention during the development of new information techniques during the past decade.

DEVELOPMENT OF NEW INFORMATION TECHNIQUES

The demands of modern research have resulted in a continuing improvement in the instruments used for conducting experiments and making observations. It became evident some time ago that it was equally necessary to develop more powerful methods and techniques for making efficient use of recorded knowledge (2). This task has not been easy and developments are still in progress. Nevertheless, the past ten years have resulted in establishment of important principles, the development of a variety of new techniques, and the acquisition of considerable experience in their practical application (3).

The impetus to developing new information techniques was provided by a realization of the limitations of conventional methods such as alphabetized indexing, pigeon hole classification, and subject-heading filing. It was pointed out over ten years ago that it is necessary to shift emphasis from putting information away in a file to the retrieval of stored information when it is needed (4). Further analysis of information requirements led to the conclusion that they involve, in a majority of cases at least, a multiplicity of concepts. It is the exceptional case that a mechanical engineer will wish to be provided with all the papers on cam mechanisms, or the chemist will wish to see all the papers dealing with methane, or a doctor will be interested in all papers on penicillin, or a lawyer in all cases dealing with accidents. In each of these examples, one or more additional concepts will almost certainly be involved in defining a realistic information requirement. The chemist, for example, may be interested in the vapor phase oxidation of methane using a vanadium oxide catalyst, or the lawyer will be interested only in automobile accidents involving railroad grade crossings (5).

To meet realistic information requirements, it is necessary, therefore, to be able to search out and to identify those papers, reports, or the like that deal with various combinations of concepts. Stated in this fashion, this requirement may be analyzed into three main steps:

(1) Analysis of items of information in terms of characteristic concepts.
(2) Analysis of information requests in terms of combinations of concepts.
(3) Matching the combinations of concepts that define information requirements with the concepts that characterize information requirements.

The final matching operation may be performed with the aid of various devices. The capabilities of these devices determine the range of information requirements that can be readily serviced and also the time and effort that must be expended in doing so.

With very simple devices, the range of requirements that can be serviced is, as might be expected, much more restricted than with other forms of equipment that are able to perform more complex operations. The older methods of analyzing information established certain fixed combinations of concepts as the means to be used in identifying publications, reports, and similar records. Once these combinations are fixed during the analysis step, they become, in effect, a framework within which it is necessary to work when searching and selecting those records containing pertinent information. Conventional classification, as practiced in the past by the U. S. Patent Office, defines various major classes and subdivisions under each of these in a fashion best described as hierarchial. An excerpt, selected at random from such a classification system, will reveal that the definition of scope of the classes and subclasses, as indicated by the headings, involves in each case a multiplicity of concepts. The limitations in capabilities of such a classification system arise from the fact that the permutation of concepts as established in defining classes and subclasses often does not correspond to the requirements of an information search, conducted, for example, to investigate the inventive novelty of a patent application (6).

In setting up combinations of concepts for defining the main classes and subdivisions within a conventional classification system, there is a tendency to make use of generic concepts of relatively broad scope. As such classifications are extended to provide finer and finer subdivisions, there is a tendency to use a larger and larger number of concepts of narrower scope. The number of different combinations among such concepts increases in an exponential manner, and this appears to be at least one of the principal reasons why this form of classification has reached or is reaching a point of diminishing returns in the patent offices of the world. During recent years, a trend has developed toward replacing the pigeon hole systems of the past with more versatile electronic equipment as outlined below (7).

Alphabetized indexing is another traditional method based on the use of a simple device, namely establishment of a well-ordered fixed array of headings. Here also, each heading, on examination, usually turns out to involve a combination of two, three, or sometimes more concepts. In such indexes it is impractical, for reasons of cost, to make extensive or thorough use of generic concepts. This limitation, together with the attendant and resultant impossibility of establishing, as index entries, the full range of combinations of concepts valid for the material indexed, have been important factors in making it increasingly difficult for alphabetized indexing to serve present-day research requirements. Another important factor is the rapidly expanding bulk of indexes. The next decennial index of *Chemical Abstracts*, for example, will consist of nineteen large volumes.

Realization of the advantages of being able to direct searching operations to combinations of concepts first became widespread as the result of pioneering work with hand-sorted punched cards (8). Such cards are furnished by the manufacturers with holes punched in single or multiple rows along the periphery. By cutting away the cardboard between a given hole and the edge of a given card, it is conditioned to drop from a searching needle inserted into the hole. Any desired meaning may be assigned to each of the punching positions in the cards of a given file. During sorting operations, those cards may be selected in which a combination of concepts has been denoted by the edge-notching of the corresponding holes. For example, a search may be directed to cards for which all of several concepts have been punched. This requirement constitutes a logical product and may be symbolized by $A \cdot B \cdot C \cdot D$, etc. Similarly, all the cards may be selected that have been edge-notched for any one of several concepts. This requirement constitutes a logical sum and may be symbolized by $A + B + C + D$, etc. Another possibility is to select all cards that have been edge-notched for some one concept but not edge-notched in the position assigned to another concept. This requirement constitutes a logical difference

and it may be symbolized by $A - B$. Searching operations may also be directed to a wide range of combinations that correspond to complex logical relationships, such as those exemplified by $(A + B)(C - D)E$ or $A \cdot B + (C - D) \cdot F$ or $(A + B)(C \cdot D + E \cdot F) - G_2$, etc.

It is obvious, however, that hand-sorted punched cards have certain inherent limitations. The number of punching positions is limited even when multiple rows of holes are provided and meaning is ascribed not only to edge-punching but also to punching out the cardboard between companion holes in adjacent rows. Assigning meaning to combinations of punching positions increases the vocabulary of concepts available for recording characteristics, but, of course, decreases the number of concepts that can be registered on any one card. Furthermore, manual sorting operations become tedious and time consuming if the file to be searched contains a large number of cards, say, in excess of a few thousand.

Studies of punched-card equipment, as developed for accounting purposes by IBM and Remington-Rand, revealed an essential limitation in the sorter (9). In order for this machine to locate an entry denoted by punching, it is necessary to know which column of the card or which punching position may have been assigned for the entry in question. This necessity of working in terms of fixed assignment of positions has meant that conventional punched-card equipment, like hand-sorted punched cards, has remained restricted in its application to relatively narrow fields of specialization (10). The extension in capabilities provided by such equipment as the IBM 101 statistical machine has not essentially altered this situation. The difficulty is by no means inherent in punched cards. They have been shown to be highly versatile as means for recording symbols in a form that can be readily sensed by automatic equipment (11). The principal difficulty is rather in the limited capabilities of commercially available punched-card sorting and selecting equipment.

Space limitations, unfortunately, do not permit a detailed review of various machine developments that have been directed to the problem of providing equipment to meet modern information requirements. A recent review indicates, however, that exceptionally versatile capabilities may be achieved by relatively simple electronic circuits, if properly designed (12). As a consequence, it is possible to construct (13), at a small fraction of the cost of a general-purpose electronic computer, a searching-selector able to perform the following functions:

(1) Use patterns, e.g., of magnetic spots, to record sequences of symbols either in tape or unit records. In this way, the characteristics of documents may be recorded one after another for subsequent search by the selector. (Individual symbols and combinations of symbols may be used to record the characteristics of documents in the same way that individual letters and combinations of letters are used to denote words in ordinary writing. It should also be noted that meaning may be ascribed to any combination of symbols as may be appropriate.)

(2) Read the tape and convert the patterns used to record successive symbols into corresponding pulses of electronic pulses, which then activate the discriminating unit.

(3) Detect those characteristics and combinations of characteristics which typify the subject contents of documents that are of pertinent interest. The discriminating unit is conditioned to detect such characteristics by appropriate wiring of a plug board prior to initiating a given search.

(4) Type out automatically the serial numbers of those documents whose characteristics correspond to the requirements of a given search. The scope of a search will be expressed by specifying that the documents of pertinent interest shall have some one characteristic or some combination of characteristics. Possibilities for specifying combinations of characteristics are outlined below.

The sequences of symbols may be organized into combinations analogous to "syllables" from which "words" may then be built up and from which, in turn, combinations analogous to "phrases," "sentences," and "paragraphs" may be built up. If the capital letters A, B, C, D, etc., are used to designate individual symbols, then letters with subscripts may be used to designate various levels of combinations as follows:

A_1, B_1, C_1, D_1, etc., for "syllables"
A_2, B_2, C_2, D_2, etc., for "words"
A_3, B_3, C_3, D_3, etc., for "phrases"
A_4, B_4, C_4, D_4, etc., for "sentences"
A_5, B_5, C_5, D_5, etc., for "paragraphs"
A_6, B_6, C_6, D_6, etc., for "messages"

This ability to organize characteristics into sets analogous to "phrases," "sentences," etc., is important in preventing false association of characteristics when searching. For example, by proper "phrasing" it is possible to prevent the properties of one chemical compound being incorrectly attributed to some other process.

At any level, which we may term the "n-th" level, each combination will consist, in general, of a number of component combinations at the "n-1" level. Each of several "n-th" level combinations, denoted by A_n, B_n, C_n, D_n, etc., may be specified in terms of component units designated by A_{n-1}, B_{n-1}, D_{n-1}, etc. Thus, in conducting a search, it may be specified, as a condition that a document will be identified as being of pertinent interest, that at least one "n-th" level combination shall be characterized by certain component units. Specification of the component units may be set up on the basis of the following relationships. It may be specified that

(1) *All of several components units must be present.* This requirement constitutes a logical product that may be symbolized, for example, by:

$$A_{n-1} \cdot B_{n-1} \cdot C_{n-1}, \text{ etc.}$$

In specifying logical products, further requirements as to order may be imposed. Thus, for example, it may be required that all components specified by a logical product shall occur in sequence. For example, it may be required that A_{n-1} shall be followed by B_{n-1} and it, in turn, by C_{n-1}. This requirement may be symbolized by

$$\left\langle A_{n-1} \cdot B_{n-1} \cdot C_{n-1} \right\rangle$$

The reverse order of these three components might also be specified as denoted by

$$\left\langle C_{n-1} \cdot B_{n-1} \cdot A_{n-1} \right\rangle$$

(2) *Any one of several component units or, alternately, one or more of several component units must be present.* This requirement constitutes a logical product that may be symbolized, for example, by

$$A_{n-1} + B_{n-1} + C_{n-1}, \text{ etc.}$$

(3) *At least one component unit must be present but at least one other component unit must be absent.* This requirement constitutes a logical difference that may be symbolized, for example, by

$$A_{n-1} - B_{n-1}$$

Here, also, order may be designated. Thus it may be

specified that B_{n-1} may not follow A_{n-1}. This requirement would be symbolized by

$$\left\langle A_{n-1} - B_{n-1} \right\rangle$$

Alternately, it might be specified that B_{n-1} may not precede A_{n-1} and this would be symbolized by

$$\left\langle -B_{n-1} + A_{n-1} \right\rangle$$

(4) *Combinations of component units expressed by complex logical relationships must be present.* Such logical relationships as the following may be specified

$$(A_{n-1} \cdot B_{n-1} - C_{n-1})\,(D_{n-1} + E_{n-1})$$
$$(A_{n-1} + B_{n-1})\,(C_{n-1} - D_{n-1})\,E_{n-1}$$
$$(A_{n-1} - B_{n-1})\,(C_{n-1}\,D_{n-1} - E_{n-1})$$

Any such complex logical relationship may be set up as required at any level. Such complex logical relationships may also involve specification of sequential order. Using the symbols < > to denote order as before, we might specify such search requirements as

$$(\langle A_{n-1} \cdot B_{n-1} - C_{n-1} \rangle)\,(D_{n-1} + E_{n-1})$$
$$(A_{n-1} + B_{n-1}) \langle (\langle C_{n-1} - D_{n-1} \rangle)\,E_{n-1} \rangle$$
$$\langle (\langle A_{n-1} - B_{n-1} \rangle)\,(C_{n-1}\,D_{n-1} - E_{n-1}) \rangle$$

Application of these capabilities means that "syllables" may be specified in terms of component symbols, e.g. letters, "words" may be specified in terms of "syllables," "phrases" in terms of "words," "sentences" in terms of "phrases," "paragraphs" in terms of "sentences," and "messages" in terms of "paragraphs."

These capabilities enable abstracts, after editing to provide standardized phrasing, to be encoded for automatic searching. In such encoded abstracts, there are no restrictions on the terms that may be used to designate characteristics of the subject contents of various kinds of graphic records. Furthermore, encoding of such terms can denote their relationship to generic concepts. For example, "thermometer" may be encoded so as to denote that it is a device to measure temperature (14). By using role indicators with various substantive terms, relationships of an observational or empirical nature may be recorded in such a form that they may serve as characteristics for use in defining automatically performed searching operations (15).

CONCLUSION

New equipment, methods, and techniques are providing new tools to facilitate the recall of information from storage. As the capabilities of these tools become better understood, their widespread application gives promise of enabling us to achieve a major advance in correlating and utilizing recorded knowledge. A key operation in this connection is the processing of large volumes of information so that the newer searching and correlating techniques may be applied to best advantage. Centralized processing of the information of interest to an entire industry or major branch of science appears to be the most economical approach. The pioneering work now being sponsored by the American Society for Metals on behalf of the metallurgical industry (16) is pointing the way to the future, not only in the broad realm of science and technology but also in other fields of professional activity, such as law and medicine.

REFERENCES

1 Rosenbaum, E. P., "Physics in the USSR," *Scientific American* **195**, no. 2, 29–35, Aug. 1946.

2 Bush, Vannevar, "As we may think," *Atlantic Monthly* **176**, 101–108, July 1945.

3 "Documentation in action," edited by J. H. Shera, J. W. Perry, and Allen Kent, New York, Reinhold Publishing Corp. In press.

4 Cox, G. J., Bailey, C. F., and Casey, R. S., "Punch cards for a chemical bibliography," *Chemical & Engineering News* **23**, 1623–1626, 1945.

5 Perry, J. W., "Information analysis for machine searching," *American Documentation* **1**, 133–139, 1950.

6 Bailey, M. F., "A history of Patent Office Classification," *J. Patent Office Soc.* **28**, 463–507, 537–575, 1946.

7 Lanham, B. E., "Chemical patent searches," *Indust. Engng. Chem.* **43**, 2494–2496, 1951; Bush, Vannevar, et al., "Report to the Secretary of Commerce by the Committee on Applications of Machine to Patent Office Operations," Dept. Commerce, Washington, D. C., Dec. 22, 1954. For more recent developments in the U. S. Patent Office, see Lanham, B. E., Leibowitz, J., and Koller, H. R., "Mechanized searching problems and developments," (paper presented to Division of Chemical Literature, American Chemical Society, 129th Nat. Meet., Dallas, Tex., Apr. 1956). Lanham, B. E., Leibowitz, J., and Koller, H. R., "Advances in mechanization of patent searching," Office of Research and Development, U. S. Patent Office, Washington, D. C., Apr. 11, 1956; Andrews, D. D., and Newman, S. M., "Storage and retrieval of contents of technical literature. Nonchemical information," Office of Research and Development, U. S. Patent Office, Washington, D. C., May 15, 1956. For an account of applications of punched-card machines and related techniques in the Australian Patent Office, see Jeffery, C. N., "Application of punched cards in patent searching," *J. Instn. Engrs., Australia* 107–110, June 1954, and also Higginson, H. L., and Poplowska, A., "Patent specifications searching in the field of organic chemistry," (paper presented to Division of Chemical Literature, American Chemical Society, 129th Nat. Meet., Dallas, Tex. Apr. 1956). (Note also that the two mentioned Dallas papers will be published in "Advances in documentation and special librarianship," Vol. I, edited by G. L. Peakes, J. W. Perry, and Allen Kent, New York, Interscience Publishers, Inc. In press.)

8 "Punched cards, their application to science and industry," edited by R. S. Casey and J. W. Perry, New York, Reinhold Publishing Corp., 1951.

9 Perry, J. W., "The ACS Punched Card Committee. An interim report," *Chemical & Engineering News* **27**, 755–756, 1949. See also, Perry, J. W., and Casey, R. S., "Mechanized searching," "Encyclopedia of Chemical Technology," Vol. 8, 449–469, 1952, New York, Interscience Publishers, Inc.

10 "Punched cards and automation of information methods," edited by R. S. Casey, J. W. Perry, and Madeline M. Berry, New York, Reinhold Publishing Corp. In preparation.

11 "New tools for the resurrection of knowledge," Staff Report, *Chemical and Engineering News* **32**, 866–869, 891, 1954.

12 Hyslop, Marjorie R., "Inventory of methods and devices for analysis, storage and retrieval of information," "Documentation in Action," edited by J. H. Shera, J. W. Perry, and Allen Kent, Chap. VI, 101–136, New York, Reinhold Publishing Corp. In press.

13 A machine having capabilities as specified is in operation at the School of Library Science, Western Reserve University. See also Cherenin, V. P., and Rakov, B. M., "The experimental information machine of the Institute of Scientific Information of the USSR," Moscow 1955. Reviewed in *American Documentation* **7**, 233–234, 1956.

14 Perry, J. W., Kent, Allen, and Berry, Madeline M., "Mechanized literature searching—a program report," (paper presented to Division of Chemical Literature, American Chemical Society, 123rd Nat. Meet., Los Angeles, Calif., Apr. 1953, published in *College and Research Libraries* **16**, 157–163, 1955). See further, Cherenin, V. P., "Nekotorye Problemy Dokumentatsii i Mekhanizatsii Informatsionnikh Poiskov (Certain problems of documentation and of mechanization of information searches)," Institute of Scientific Information, Academy of Sciences USSR, Moscow, 1955. (To be reviewed in *American Documentation*).

15 Perry, J. W., Kent, Allen, and Berry, Madeline M., "Machine literature searching," New York, Interscience Publishers, Inc., 1956.

16 Kent, Allen, Perry, J. W., and Booth, R. E., "Automation in literature research—a report on the ASM mechanized literature searching project," (paper presented before Nat. Meet., American Society for Metals, Cleveland, Ohio, Oct. 11, 1956).

"Letters to the Editor" and "Books Received for Review" appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 3488, 3491, 3495, 3497, 3498, 3499, 3500, 3510, 3526, 3529, 3532, 3542, 3574, 3578, 3587, 3589, 3608, 3659, 3683, 3684, 3685, 3723, 3730, 3763)

Book—3466. McLachlan, N. W., Ordinary non-linear differential equations in engineering and physical sciences, 2nd ed., London, Oxford University Press, 1956, 271 pp.

Book is revised edition (first edition reviewed in AMR **4,** Rev. 991) containing numerous additions. These include: material relating to the stability of softening systems, discussion of singular points and graphical solutions, derivations of differential equations satisfied by Jacobian elliptic functions, several theorems relating to free and forced oscillations, and a chapter containing the analysis of a nonlinear ordinary differential equation occurring in boundary-layer theory. Only single-degree-of-freedom systems are considered.

Reviewer feels that the book is somewhat unusual in that he is left with the distinct impression of reading a collection of solutions to particular problems, rather than an exposition of general methods supplemented by specific examples. This leaves one with an impressive array of physical problems in which nonlinearities occur and are amenable to treatment; students may, however, be left also with the feeling that there are few general methods of solutions which apply to broad classes of problems, contrary to fact. The net result might be construed as a book valuable to the student for an introduction to the subject and as a collection of nonlinear problems; the engineer confronted with nonlinear systems will also find this book of much value. However, both groups will find also that a supplementary text containing a more general exposition of analytical *methods* will be extremely helpful.

Inclusion of additional material on graphical solutions in present edition is welcome, although the presentation may lack the details requisite to a complete understanding of the techniques.

Reviewer finds book to be written in the customary readable style of the author and is sure that it will prove to be valuable for both classroom and office use. The reference list is excellent as are the more than fifty problems for student solution given in an appendix; these add greatly to the value of the book for classroom use.

H. N. Abramson, USA

Book—3467. Birger, I. A., Some mathematical methods for solving engineering problems [Nekotoriye matematicheskiye metodi resheniya inzhenernykh zadach], Moscow, Gosud. Izdat. Oboron. Prom., 1955, 151 pp. 5r. 70k.

Mathematical treatment of several important questions in engineering leads to solving boundary-value problems for ordinary differential equations. A. N. Krylov has pointed to the role of normal fundamental functions for such significant technical cases as the action of concentrated loads, moments, etc., where the desired solution or its derivatives must have certain discontinuities. If the problem reduces to differential equations with variable coefficients then it is often useful to apply the efficient methods of integral equations.

Chapters 1 and 2 of the book under consideration explain theory and use of normal functions in the case of ordinary differential equations, both with constant and with variable coefficients. The remaining two chapters are devoted to integral equations and their applications in engineering. Author illustrates general methods on various problems of elasticity and theoretical mechanics (vibrations, stability, etc.), but it is evident how they can also be applied in other branches of engineering.

Presentation is clear and vivid. The book does not require any special mathematical equipment and so will certainly be useful to calculating engineers and physicists.

V. Vodička, Czechoslovakia

3468. Langefors, B., On the practical solution of linear equations, *SAAB Aircraft Co., Linköping, TN* 35, 24 pp., 1955.

Use of inverse matrixes is compared with results from elimination work for obtaining solutions to systems of equations which have previously been solved for other right-hand members. Some procedures for approximately solving systems of equations and for iterative solutions are further discussed and a new approach to solution of such equations, which may be established by the aid of matrix transformation, is suggested.

From author's summary by L. Villena, Spain

3469. Ershov, A. P., Method for the inversion of a matrix (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **100,** 2, 209–211, 1955.

Constructing the inverse of a nonsingular quadratic matrix A of order n is equivalent to solving a system of linear equations and is of nontrivial nature only if n is large. Author suggests two recursive procedures yielding A^{-1} in n or $2n$ steps, respectively. First one starts with unity E as initial approximation for A^{-1} and after m steps leads to matrixes in which only the first m rows are different from those of E. Second procedure starts with $A - E$ instead of E and follows similar lines.

Only under very special circumstances can less than the full number of steps bring about a useful approximation in either case.

G. Plato, USA

3470. Kotel′anskiĭ, D. M., Bounds for determinants of matrixes with dominant principal diagonal (in Russian), *Izv. Akad. Nauk SSSR Ser. Mat.* **20,** 1, 137–144, Jan./Feb. 1956.

A matrix $B = \| b_{ik} \|_1^n$ with $b_{ii} > 0$, $b_{ik} < 0$, $\sum_{j=1}^{n} b_{ij} > 0$ $(i, k = 1, 2, \ldots, n, i \neq k)$ is called to be of the type M. There corresponds, to any matrix $A = \| a_{ik} \|_1^n$ with dominant principal diagonal, the M-matrix $B = \| b_{ik} \|_1^n$ with the elements $b_{ii} = |a_{ii}|$, $b_{ik} = -|a_{ik}|$ $(i \neq k)$.

Author establishes the inequality $|detA| \geq detB$ and gives new estimates for determinants of the matrixes in question, improving substantially the existing bounds deduced by Price, Ostrowsky, and others. The results may doubtless be of importance in engineering, e.g., in the advanced theory of vibrations.

V. Vodička, Czechoslovakia

Book—3471. Matveev, N. M., Methods of integrating ordinary differential equations [Metodi integrirovaniya obyknowennykh differentsialnykh uravenii], Izdat. Leningr. Univ., 1955, 655 pp. 22r.

This is certainly one of the best Russian works on the subject. Originated over the teaching period of several known specialists [Gyunter, Erugin, and, at present, Matveev) at the mathematico-mechanical faculty of the Leningrad University, book brings a detailed, masterly presentation of classical methods applied in the field of ordinary differential equations. It presents a number of new results, among them much material from Russian research work. Finally, it opens broad vistas to further possibilities and development in this branch of science.

The extraordinary care in writing and printing the volume strikes one at the first glance. There is not the slightest appearance of the inaccuracies and misprints often burdening, in the well-known unpleasant manner, even the excellent publications of the Russian literature. Paper and print are excellent, typographical form faultless. There are 50 beautiful and instructive figures throughout the text.

Book opens with a fine introduction on the character of problems treated in the theory of ordinary equations. Chapters 1–4 deal with the first-order equations, then with normal systems of differential equations, and, finally, with equations of n-th order. These beginning sections constitute an unusually detailed survey

of all fundamental concepts and elementary classical methods of integrating differential equations.

Of central importance is the 5th chapter (almost 200 pages) devoted to the existence and uniqueness theorems (Picard, Peano, Cauchy). The stability questions in the sense of Lyapunov are treated in connection with the continuous de, endence of solutions upon parameters and initial values. Singular points of a first-order equation and of a normal system of equations are also considered and so is the general theory of singular solutions.

Following two sections have for subject general discussion of the nth order equations (both with variable and with constant coefficients). Chapter 8 deals, by methods of analytic theory of differential equations, with some supplementary facts about the equations of second order. Such is the method of integrating by generalized power series, applied to Bessel and hypergeometric equations.

General theory of linear systems with variable and constant coefficients forms the subject of chaps. 9 and 10, whereas the use of matrixes in the case of linear homogeneous systems of equations is explained in chap. 11. The last section gives fundamental results from the theory of partial differential equations of first order.

Perfect theoretical explanation of each concept, each definition, and theorem is followed by numerous and instructive worked-out examples. References are given throughout the text, along with theoretical discussion of related subject.

The work under consideration does not follow any special direction; it is concerned rather with all three basic branches of this domain of mathematics, i.e., with the qualitative and analytic theory of differential equations and with the Lyapunov stability theory. If anyone wishes to gain a good knowledge in the vast field of ordinary differential equations, then it is sufficient, in reviewer's mind, to peruse the present book by Matveev and then to improve and complete his knowledge by a conscientious study of the more advanced brilliant work by Coddington and Levinson [AMR **9**, Rev. 352]. V. Vodička, Czechoslovakia

3472. Biot, M. A., Applied mathematics, an art and a science, *J. aero. Sci.* **23,** 5, 406–410, 489. May 1956.

3473. Krasovskiĭ, N. N., On the stability as a whole in the solution of nonlinear differential equation systems (in Russian), *Prikl. Mat. Mekh.* **18,** 6, 735–737, 1954.

A criterion for stability of evident solutions of nonlinear differential equations

$$\frac{dx_i}{dt} = X_i\,(x_1, \ldots\ldots, x_n)\ (i = 1, \ldots\ldots, n)$$

where X_i are continuous and differentiable for $-\infty < x_i < \infty$ $(i = 1, \ldots\ldots, n)$ and vanish at 0 $(0, \ldots\ldots, 0)$, is obtained as follows:

If we take

$$\frac{\partial X}{\partial x} = \left\| \begin{matrix} \dfrac{\partial X_1}{\partial x_1} \cdots\cdots \dfrac{\partial X_1}{\partial x_n} \\ \\ \dfrac{\partial X_n}{\partial x_1} \cdots\cdots \dfrac{\partial X_n}{\partial x_n} \end{matrix} \right\|$$

in order that evident solutions $x_1 = \ldots\ldots = x_n = 0$ of equations given are stable as a whole asymptotically, it is sufficient that there exists a constant matrix

$$A = \left\| \begin{matrix} a_{11} \cdots\cdots a_{1n} \\ \\ a_{n1} \cdots\cdots a_{nn} \end{matrix} \right\|$$

which has positive eigenvalues, and a symmetrical matrix

$$\frac{1}{2}\left(\left\{A\frac{\partial X}{\partial x}\right\}_{ik} + \left\{A\frac{\partial X}{\partial x}\right\}_{ki}\right)$$

has such eigenvalues λ_i as to satisfy the inequalities

$$\lambda_i < -\delta\ (i = 1 \ldots\ldots, n)$$

in the whole space $\{x_i\}$, δ being a positive constant.

M. Kataoka, Japan

3474. Starzhinskiĭ, V. M., Remarks on the study of the stability of periodic motions (in Russian), *Prikl. Mat. Mekh.* **19,** 1, 119–120, 1955.

In this short note it is shown that the investigation of stability of the trivial solution of two linear differential equations of first order with periodic coefficients can be reduced to the investigation of stability of the trivial solution of a homogeneous differential equation of second order without damping term having a continuous and periodic coefficient. In this way, Lyapunov's method for stability consideration may be used in the case treated by the author. J. Beránek, Czechoslovakia

Book—3475. Wass, C. A. A., Introduction to electronic analogue computers, New York, McGraw-Hill Book Co., Inc., 1955, ix + 237 pp. $6.50.

This is the first English text devoted entirely to analog methods of computation. In general, it is closely patterned after earlier U. S. texts. The basic concepts of machine calculations are presented with an appraisal as to the types of problems most suited for each classification. These include analogs, differential analyzers, and analog and digital computers. Basic circuitry is presented for each of the necessary computing elements, including a rather lengthy discourse on electrical and electromechanical function generators. Considerable space is devoted to feedback and stabilization of the various computing elements and to the discussion of their inherent inaccuracies.

The most interesting idea presented is a division of the general class of analogs or simulators. These are generally considered to be electrical, hydraulic, or mechanical models of a system whereby measurements of occurrences on the model may be related to the same occurrences within the system. Often the equations governing the system are not needed for the solution of the problem, other than to derive the conversion factors for the analogous device. The approach which is most discussed in this book might be described as a mathematical model or analog whereby each element in the system is replaced by a computing element which will solve the equations governing the behavior of that portion of the system. These computing elements are then compounded in their relative positions to gain the solution to the general problem. This computing technique involves the solution of a number of equations of low order rather than a single equation of higher order, and is unique in point of view rather than in its application. The remainder of the book is devoted to descriptions and illustrations of a number of existing computers such as Tridac.

The text, though devoted largely to electronic circuitry, does not demand a thorough understanding of electronic principles in order to present the fundamental concepts of the application of analog techniques. The presentation is easy to read and should be of value to those interested in this general field.

G. Damewood, USA

3476. Weiss, G., and Lindner, J., In analoging—where you should use series or parallel summation, *Control Engng.* **3,** 6, 77–84, June 1956.

The most elementary operation in analog computers is summation—that is, addition and subtraction. These operations can be carried out in a number of ways in electrical analog computing

equipment. The two most common methods are series summation and parallel summation.

In discussing the relative merits of these methods, authors point out many problems and impart solutions that result in desired equipment operation. Comparison of the methods of series summation and parallel summation are handily reviewed in an accompanying table. From authors' summary

3477. Householder, S., Bibliography on numerical analysis, *J. Assn. Comp. Machy.* **3,** 2, 85–100, Apr. 1956.

This list of books and articles in the field of numerical analysis is intended to supplement and bring up to date one published by the present writer as an appendix to his *Principles of Numerical Analysis* [McGraw-Hill, 1953]. In the two years since its preparation a number of omissions have been noted. More to the point, however, has been the rapid growth of interest in the subject and the concomitant proliferation of the literature. As a byproduct and aid to one person's endeavor to keep up with the field, the supplementary list has grown to a length comparable to that of the original. Admittedly it is incomplete, and doubtless always will be. Nevertheless, with the encouragement of some, it is offered for such help as it may provide to others who are trying to find their way about. The bibliography contains 320 entries.

From author's summary

3478. Gray, H. J., Jr., Propagation of truncation errors in the numerical solution of ordinary differential equations by repeated closures, *J. Assn. Comp. Machy.* **2,** 1, 5–17, Jan. 1955.

Book—3479. Neville, E. H., Rectangular-polar conversion tables, (Royal Society Mathematical Tables, Vol. II), New York, London; Cambridge University Press, 1956, xxix + 109 pp. $5.50.

Let $x = r \cos \theta$, $y = r \sin \theta$. For x, $y = 1(1)105$, principal table gives r to 13d, $\ln r$ to 15d, θ in radians to 15d and θ in degrees to 13d. Preparation, checking, and interpolation of tables are described in the introduction. A bibliography by J. C. P. Miller is included. There are six supplementary tables. I. $\ln x$, $x = 1(1)160$ to 15d, II. $x \ln 10$, $x = 1(1)20$ to 15d. Table III gives adjusting factors to assist in the interpolation of $\ln r$. The Farey integer-series of order 105 is in Table IV. For a given r, the location of $\ln r$ in the main table is detailed in Tables V and VI. The printing and typography are excellent.

Y. L. Luke, USA

Book—3480. Miller, J. C. P., Tables of Weber parabolic cylinder functions, London, Her Majesty's Stationery Office, 1955, 233 pp. $11.68.

This is a valuable volume. Title functions arise in numerous applied problems. They were originally introduced to solve the two-dimensional wave equation in parabolic coordinates, and are applicable, for example, to study wave motion in bays with parabolic shores or around parabolic capes. Consider the mass-spring oscillator equation $d^2y/dx^2 + K(x)y = 0$. For constant K, the solution is elementary. If K is linear in x, then Airy functions are appropriate. In many problems, the stiffness factor is quadratic, and here the parabolic functions are pertinent.

The standardization adopted in the present work is (1), $K_1(x) = -(x^2/4 + a)$; and (2), $K_2(x) = (x^2/4 - a)$. A detailed mathematical investigation is presented in nine sections. These include series representations (convergent and asymptotic), integral representations, standard solutions, relation to other functions, etc. Many results are recorded here for the first time. Sections 10–13 deal with description and preparation of tables. A compendium of functions and formulas relating to (1) and (2) are given (pp. 61–89). There is a bibliography.

Tables relating to (1) are already available, but those for (2) have for the most part been neglected. The present volume fills this gap. Standard solutions adopted for tabulation are notated $W(a, x)$, $W(a, -x)$. These, together with reduced derivatives, are presented in Table I for $a = -10(1)10$, $x = 0(0.1)10$. At least 8 significant figures are available. The reduced derivatives facilitate x-wise interpolation. Other interpolatory techniques are described, and Tables II and III present auxiliary functions for this purpose. Tables IV to VI give values of various constants and gamma functions which arise in the theory of $W(a, \pm x)$.

Y. L. Luke, USA

Book—3481. Warmus, M., Evaluation of logarithmic tables and tables of natural logarithms for 36 decimals [Sur l'evaluation des tables de logarithmes et tables des logarithmes naturels a 36 decimales], (Prace Wroclawskiego Towarzystwa Naukowego Ser. B, no. 52), Wroclaw, Panstwowe Wydawnictwo Naukowe, 95 pp., 1954 (paperbound).

Part I is an exposition of well-known factorization technique for calculation of logs. It is written in French. Tables are given in part II. All are to 38d; the extra decimals serve as guard units in further manipulation so that in most instances 36d accuracy can be achieved. Tables are as follows: I—$N \ln 10$, $N = 1(1)50$; II—$\ln N$, $N = 1.0(0.001)9.999$; III—$\ln N$, $N = 1.0(0.0^31)1.0099$; IV—$\ln N$, $N = 1.0(0.0^51)1.0^499$; V—$\ln N$, $N = 1.0(0.0^61)1.0^6100$. Description and formats for use of tables to calculate logs and anti-logs are presented in the introduction. Here each page is split into two parts. The left-hand side is in French; the text of the right-hand side is the same, but in Russian. This should serve as an excellent opportunity to gain an introductory reading knowledge of Russian, provided one knows French.

Y. L. Luke, USA

3482. Meyer-Eppler, W., Technical application of modern correlation methods (in German), *ZVDI* **98,** 13, 600–604, May 1956.

Author reviews some of the more important uses of autocorrelation: noise reduction, obtaining power spectra, signal analysis, time domain filtering, and direction finding. He also touches briefly on methods for obtaining autocorrelation functions and on two-dimensional autocorrelation. C. M. Crain, USA

3483. Lyle, P., The construction of nomograms for use in statistics, *Appl. Statistics* **3,** 3, 184–195, Nov. 1954.

3484. Vaughan, W. L., Simplified graphical integration, *Prod. Engng.* **27,** 8, 223–225, Aug. 1956.

3485. Cunningham, W. J., Graphical solution of certain nonlinear differential-difference equations, *J. Franklin Inst.* **261,** 6, 621–629, June 1956.

Method of solution applies to nonlinear first-order differential equations with a single time lag. Similarities and distinctions are pointed out between this type of equation and ordinary second-order differential equations. Graphical solution proposed for the former is patterned after the method of isoclines in the phase plane for the latter, and is probably equally tedious. Several illustrative examples are given. R. Drenick, USA

3486. Fick, E., Conformal mapping through elliptic functions (in German), *ZAMM* **34,** 10/11, 416–429, Oct./Nov. 1954.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3474, 3517, 3586, 3735, 3795, 3796, 3797)

3487. Altmann, F. G., Spatial mechanisms (in German), *Feinwerktech.* **60,** 3, 80–92, Mar. 1956.

In an introduction author recalls that mechanisms used for moment or angular velocity transformation can be classified,

according to the distance a and the angle δ between their axes, into plane ($a \geq 0$, $\delta = 0$), spheric ($a = 0$, $\delta > 0$), and spatial ($a > 0$, $\delta > 0$) mechanisms. To permit a general view on their constitution, the latter are divided in two groups, one with constant velocity ratio, another with variable velocity ratio. For the first group, containing, in general, toothed surfaces (figures of toothed cylinders, cones, and so on, are given), the formal stand and the actual problems are briefly delineated. In the second group are considered only the kinematic chains, the members of which are linked together by surface contact. Based on a generalization of the well-known Grubler criterion, the total number of degrees of freedom for the different joints of a desmodromic chain is given in function of the number of members and the number of joints. Numerous examples and their applications to the connection between two shafts are given. Author also distinguishes here two groups; the first one concerns the mechanisms for which deformation of the members has no influence on the transmission of motion and for which the general relation given for the total number of degrees of freedom holds; the second group contains the mechanisms for which this total number is smaller than that given by the general relation; for the latter, the relative positions of shafts and bearings, during the motion, has to be maintained.

Attention is called to the utility of a systematic study of spatial mechanisms for practical use.

D. DeMeulemeester, Belgium

3488. Rosenauer, N., Synthesis of four-bar linkages with prescribed reduction ratio limits: application of complex variables, *Austral. J. appl. Sci.* **7,** 1, 1–9, Mar. 1955.

A simplified method using complex variables has been deduced for use in designing a four-bar linkage in which, for a uniform rotation of the driving crank, the output angular velocity of the follower crank has prescribed extreme values. Application of the method to a particular case is given and a check is made on the validity of the solution.

From author's summary by L. W. Hu, USA

3489. Kislitsyn, S. G., Investigation of the steady-state motion of machines subjected to forces dependent on the velocity and position of the actuating link (in Russian), *Trudî Inst. Mashinoved.* **15,** 57, 61–78, 1955.

Article gives two methods by which steady-state periodic motion of a machine can be found by successive approximations: (1) kinematic method, in which angular velocity (as a function of position) is found by successive approximations, starting from any assumed function which has period 2π; (2) kinetic method, which is similar except that kinetic energy (as a function of position) is found by successive approximations. For both methods, conditions to be satisfied are (1) derivative of kinetic energy with respect to angular position equals applied torque; (2) integral of applied torque with respect to angular position is zero for a complete cycle. Example shows that kinetic method converges toward exact solution in fewer steps, but kinematic method requires less calculation for each step. Convergence of both methods is established from rigorous mathematical viewpoint.

Methods are applied for approximate calculation of flywheel inertia required to reduce speed fluctuation of machine by a specified amount. T. P. Goodman, USA

3490. Rabinowicz, E., Autocorrelation analysis of the sliding process, *J. appl. Phys.* **27,** 2, 131–135, Feb. 1956.

Size of actual contacts of two surfaces pressed together is deduced from correlation analysis. Assuming (1) constant load, (2) constant total area made up by asperities of circular cones, (3) shear strength of the oxide film is half of the metal contact, and (4) a contact may have any shear strength between those extremes with equal likelihood, autocorrelation function of friction traces is theoretically deduced. Correlation for rectangular surface asperities also is theoretically calculated. Comparing with correlation obtained from real friction traces, average junction diameter of 9×10^{-4} cm is estimated in good agreement with results obtained by other methods. From a different approach involving standard deviation of friction, a value of 5×10^{-4} cm is deduced, suggesting actual range in shear strength to be less than postulated factor of 2:1. Y. Takahashi, USA

3491. Gruenberg, R., Radius of curvature of parabolic cams, *Prod. Engng.* **27,** 8, 219–221, Aug. 1956.

3492. Clyde, D. H., The problem of sway in moment distribution. General treatment using concept of virtual work, *Engineering* **181,** 4709, 457–459, June 1956.

Author shows that the so-called sway corrections in a moment-distribution analysis may be formally treated in a similar manner to the basic joint-balancing procedure. This leads to a simplification of the preliminary work in an actual analysis and a better understanding of the significance of such operations. The treatment assumes a knowledge of the method of moment distribution and consequently does not discuss the underlying assumptions or the type of problem for which the method is suitable.

From author's summary

3493. Libby, C. C., Driving high-inertia loads, *Prod. Engng.* **27,** 4, 142–147, Apr. 1956.

How to select the best combination of flywheel inertia and motor for the cyclic power requirements of a constant-running machine such as a punch press; data on motor speed-torque characteristics under cyclic loads. A time-saving yet precise procedure based on analysis of a large number of typical drives.

From author's summary

3494. Carlevaro, M., On the calculation of the torque required by a radar antenna (in Italian), *Aerotecnica* **36,** 1, 24–26, Feb. 1956.

The calculation of the torque necessary to revolve a curved surface in a uniform wind, as a radar antenna, is made possible by the discontinuity of the elements resisting the wind.

It is possible to find the value of the torque, which is proportional to the first power of the wind speed. It is also possible to find the optimum position of the driving axis in order to obtain the minimum mean value of the torque, and to suppress its first-order oscillating component. From author's summary

Book—3495. Kosmodemyanskiĭ, A. A., A course on theoretical mechanics [Kurs teoreticheskoi mekhaniki], Moscow, Gos. Uch.-Pedag. Izdat. Min. Prosv. RSFSR, 1955, 656 pp. 12r.35k.

This is a revised second edition of the textbook for students of pedagogical institutes in Russia. Content is grouped in four main parts (kinematics, kinetics, mechanics of bodies with variable mass, aerohydrodynamics) and the subject is presented in a very readable way, in accordance with the purpose of the book. There are 256 figures throughout the text.

The study presupposes only an adequate knowledge of advanced calculus, vector analysis, and principles of the theory of functions of a complex variable. Reader's attention is called especially to third main part dealing, in its four chapters and 21 subtopics, with mechanical problems of bodies with variable mass. These important questions go beyond the standard program of usual courses and show many results obtained by the Russian savants.

The work is recommended to everyone; all will quickly and readily gain general theoretical foundations of mechanics.

V. Vodička, Czechoslovakia

Servomechanisms, Governors, Gyroscopics

(See also Revs. 3709, 3718, 3719, 3795, 3797)

3496. Coon, G. A., How to find controller settings from process characteristics, *Control Engng.* **3,** 5, 66–76, May 1956.

Paper reviews methods of obtaining "optimum" controller settings when process characteristics are known. Controller modes considered are proportional, proportional plus reset, and proportional plus rate. Methods discussed are: (a) Ziegler-Nichols formulas based on reaction rate and effective lag obtained from process reaction curve; (b) Ziegler-Nichols formulas based on ultimate values of sensitivity and period which can be obtained from either closed-loop cycling or process frequency response; (c) a techique which yields a ¼ decay ratio on the process recovery curve following a step change disturbance. This method requires that the process frequency response be known; (d) control parameter charts which are based on ¼ decay ratio. To use these charts it is necessary to know dead time, principal time constants, and process sensitivity. Author discusses at length possible benefits to be derived from use of rate action. The theoretical bases of the various methods can be obtained from the bibliography.

Paper should be of special interest to anyone concerned with plant startup or operation. S. Z. Dushkes, USA

3497. Goodman, T. P., and Reswick, J. B., Determination of system characteristics from normal operating records, *Trans. ASME* **78,** 2, 259–271, Feb. 1956.

A lucid exposition of Y. W. Lee's method for determining linear-system impulse response from cross correlation of system input and output and autocorrelation function of system input, particularly useful with random input signals. Exposition is based upon results obtained with delay-line synthesizer similar to that developed by Stutt and others. Paper includes interesting discussion of effects of noise entering closed-loop system at points other than input when impulse responses of loop components are being measured. J. G. Truxal, USA

3498. Stout, T. M., Nonlinearity in control systems. Part I. Basic principles, *Control Engng.* **3,** 2, 57–62, Feb. 1956.

Nonlinear systems are defined and examples given. Various methods of representing nonlinearities are given, including the describing function and equivalent gain. Inherent nonlinearities, such as backlash and saturation, are treated, as well as the deliberate use of nonlinearities to improve system performance. Small versus large signal nonlinearities, and nonsymmetrical nonlinearities are some of the types discussed. Various effects of nonlinearities on system performance are described.

The reviewer feels that Dr. Stout's exposition is a particularly lucid introduction to nonlinear control theory.

R. Oldenburger, USA

3499. Kochenburger, R. J., Nonlinearity in control systems. Part II. Methods of analysis and synthesis, *Control Engng.* **3,** 3, 82–91, Mar. 1956.

Professor Kochenburger carries through an analysis of a contactor servomechanism by phase plane and describing function techniques to bring out their respective advantages. The transient response approach is also discussed. The role of the analog computer in the study of nonlinear systems is brought out. Reviewer believes that the listing of eight practical control tips for the use of nonlinear techniques should be of considerable value to the reader. R. Oldenburger, USA

3500. Stout, T. M., Nonlinearity in control systems. Part III. Deliberately nonlinear systems, *Control Engng.* **3,** 4, 77–85, Apr. 1956.

Author treats the use of nonlinear elements in a control system to make the system simpler, cheaper, and smaller, to compensate for inherent nonlinearities, and to optimize system performance. Switching criteria to yield optimum transients (minimum time and no overshoot) are given for second- and third-order servomechanisms with saturation. R. Oldenburger, USA

3501. Brooks, R. W., How numerical control works, *Automation* **3,** 2, 45–51, Feb. 1956.

The theoretical aspects of symbolic logic which treat with the truth or falseness of a given relation under a specified set of conditions are well known. The application of these concepts to mechanical and electrical systems has been assuming significant importance for a number of years. In particular, the applications of symbolic logic are extremely profitable in the design of modern high-speed digital computers and similar apparatus.

Author briefly reviews the logical connectives: *and*, *or*, *not*, and then illustrates by constructing a number of functions which make use of them. In particular, he demonstrates how the four-gate 3C-PAC package of the Computer Control Corp. can perform all the logical functions of three variables. Applications of these gating packages are made to binary arithmetic operations.

This clearly written paper treats with a significant field of technology. As digital devices become larger and more complex, it becomes imperative to systematize components into fundamental units or logical building blocks. These make for economies in mass production and in assembly and debugging of the final units. By the application of symbolic logic it is possible to design a computer with gating packages which would lead to a minimum number of components, and thus increase reliability and decrease total hardware costs. J. W. Fischbach, USA

3502. Davidson, G. M., and Nashman, L., Putting stabilization to work, *Control Engng.* **3,** 1, 78–84, Jan. 1956.

Stabilizing and damping techniques to improve dynamic operation of servos are described with emphasis on network stabilization. Techniques for designing d-c lead networks and for converting to a-c networks are tabulated. Other ways to provide auxiliary damping are given, including advantages and disadvantages of each. An example is included.

Reviewer believes this material is merely a rough summary of well-known procedures [Brown, G. S., and Campbell, D. P., AMR **2,** Rev. 702; Chestnut, H., and Mayer, R. W., AMR **5,** Rev. 2278]. Methods described are highly approximate and can lead to undesirable behavior in some cases. Authors ignore important alternative procedures and fail to warn about limitations of proposed methods. L. A. Gould, USA

3503. Rama, S., On the stability of central heating plants on one floor with top return system (in Italian), *Termotecnica* **9,** 11, 548–568, Nov. 1955.

3504. Wallach, B. H., Rotational vibration response of inertial instruments, *J. aero. Sci.* **23,** 6, 605–606 (Readers' Forum), June 1956.

3505. Coon, Geraldine A., How to set three-term controllers, *Control Engng.* **3,** 6, 71–76, June 1956.

3506. Washburn, W. D., and Milham, R., Terminology of control valves, *Instrum. and Automat.* **29,** 5, 901–903, May 1956.

Vibrations, Balancing

(See also Revs. 3466, 3504, 3730, 3731, 3748)

3507. Bogdanoff, J. L., and Horner, J. T., Torsional vibration of rotating twisted bars, *J. aero. Sci.* **23,** 4, 393-395 (Readers' Forum), Apr. 1956.

The torsional frequencies of rotating bars are influenced by the angular velocity, this influence being dependent upon the base setting angle, the radius of the base, and the pretwist. The relations to determine this influence approximately are derived. Graphs and numerical results on the influence of rotation on the first three natural frequencies of a uniform fixed free bar having different base setting angles and constant pretwist rates are given. From authors' summary by J. W. Cohen, Holland

3508. Deresiewicz, H., Symmetric flexural vibrations of a clamped circular disk, *J. appl. Mech.* **32,** 2, p. 319 (Brief Notes), June 1956.

This brief note presents the high-frequency spectrum for the case of free, axially symmetric vibrations of a circular disk with clamped edges. It supplements the paper by the author and R. D. Mindlin, "Axially symmetric flexural vibrations of a circular disk," AMR **8,** Rev. 2268. The latter paper dealt with a traction-free boundary.

The theory used includes the effects of rotatory inertia and transverse shear deformation. Results are compared with the classical theory given by Rayleigh. J. Michalos, USA

3509. Kumaraswamy, M. P., and Cadambe, V., Experimental study of the vibration of cantilevered isosceles triangular plates, *J. sci. indust. Res., India* **14B,** 2, 54-60, Feb. 1956.

An experimental method for obtaining higher normal modes of vibration of cantilever plates and for precise measurement of frequencies has been outlined. The merits of various methods of exciting the natural vibrations are also described. The nodal patterns for the first 18 modes of vibration of a triangular cantilever plate are discussed. From authors' summary

3510. Ehrich, F. F., A matrix solution for the vibration modes of nonuniform disks, *J. appl. Mech.* **23,** 1, 109-115, Mar. 1956.

In this paper the problem of vibration of an axisymmetric thin disk of nonuniform thickness is treated by reducing the actual disk to a discontinuous system of circumferential strips of two kinds. First, the mass strips include the local surrounding mass of the disk as well as the local mass moment of inertia, but have no elastic properties or physical dimensions. Secondly, the massless strips of constant thickness connecting any two adjacent mass strips possess the average local bending properties of the actual disk.

It is shown how the equations describing the states of deflection, slope, moment, and transverse force in any circumferential disk element can be replaced by a single matrix equation. A recurrence formula in matrix form is stated in order to express the change in the fundamental variables by passing from the kth strip to the $k + 1$ th. This formula allows satisfaction of the boundary conditions at the outer and inner edge of the disk; successive approximations should be used, however. A special formulation is used in the case of zero inner radius of the disk.

In this way a convenient method is obtained for computation of the natural frequencies of nonuniform thickness disks, including effects of superposed masses, moments of inertia, and the effects of residual stresses, centrifugal stresses, and elastic restraints.

J. Beránek, Czechoslovakia

3511. Mansfield, E. H., The theory of torsional vibrations of a four-boom thin-walled cylinder of rectangular cross-section, *Aero. Res. Counc. Lond. Rep. Mem.* 2867, 16 pp., 1955.

The torsional vibrations of a four-boom cylinder of doubly symmetrical rectangular cross section are considered, and the differential equation of motion is derived on the assumption that the ribs maintain the section shape but do not themselves resist any warping out of their plane and that the walls of the cylinder are effective only in shear.

Frequency equations are derived for a length of cylinder, free at both ends and prevented from rotating at the mid-section. The complete behavior of the cylinder is determined by two nondimensional parameters and curves are given from which the frequencies for any such cylinder may be determined. It is shown that the higher frequencies in particular may be underestimated by between 40 to 80% if warping constraint effects are ignored.

An approximate method is given for estimating the torsional frequencies of a cylinder with nonuniform characteristics.

From author's summary by S. Sjöström, Sweden

3512. Grigolyuk, E. I., Theory of round cylindrical shells with rigid longitudinal ribs (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 62-65, Nov. 1954.

Strength, vibration, and stability of round cylindrical shells strengthened by closely spaced longitudinal ribs are investigated. An equivalent thickness is used in the longitudinal direction. After making some justifiable approximations, equilibrium and deformation equations are written. The final equations are written with the use of a force function.

A case with specific boundary conditions is discussed, and the displacement and force functions indicated for strength, stability, and vibration problems. Pressure on shell is expressed in a double trigonometrical sine series. Constants are evaluated in general terms. Stability of shell is reduced to finding relation of external normal pressure to axial force per unit length.

There are typographical errors, and the use of equivalent thickness needs clarification. S. Sergev, USA

3513. Egupov, V. K., Vibration and stability of flat, beamed ceilings (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 87-92, Oct. 1954.

To permit solutions for more than the "rare cases" previously handled, author has developed method of analysis of "beamed ceilings" based upon the use of "serial frequencies, critical powers, and the idea of dividing the ceiling into two systems of beams with equal frequencies set upon imaginary elastic supports." The result is that a larger class of problems can be dealt with rationally, including the special cases that already have known solutions. Author restricts his discussion primarily to frequency determination, but indicates that the methods are applicable to stability determinations. The discussion is quite broad and general. No specific calculations are given. Paper will probably be of most interest to applied mathematicians.

R. A. Burton, USA

3514. Reynolds, T. E., Theory of the forced vibrations of a ring with radial elastic support subjected to uniform external pressure, *David W. Taylor Mod. Basin Rep.* 836, 11 pp., Aug. 1955.

A theory of Wenk [AMR **4,** Rev. 1015] for inextensional vibration of a circular ring with radial elastic support is extended to include the effects of viscous damping and uniform external pressure. Lagrange's equations of motion are developed for free vibration under external pressure and for steady-state response of the ring to the simultaneous action of external pressure and a radial vibratory exciting force concentrated at one point. Expressions are obtained for the natural frequencies and displacements at resonance and the variation of these quantities with pressure. Curves of these results show a nonuniform increase in displacements at resonance with rising pressure for a constant driving force such that peaks appear in the curves because of the coincidence of two natural frequencies at certain pressures. Reviewer

notes that misprints are contained in Eq. (19), Fig. (1), and Fig. (2), and that Eq. (27) is in error. G. C. K. Yeh, USA

3515. **Fuhrke, H., Determination of frame vibration with the help of matrix calculation** (in German), *Ing.-Arch.* **24**, 1, 27-42, 1956.

Method developed in a previous paper [AMR **9**, Rev. 1008] now is applied to investigate vibrations of frames. Hence the vector significant for the geometrical and dynamical state of a cross section is to be completed by two components. Frame vibrating in its own plane requires additional consideration of longitudinal displacements and normal forces, lateral vibration, and the twisting angle and torsional moment. These vectors, consisting of six components corresponding to the end cross sections of each field, are connected by matrixes extended analogically. Similar simple matrixes give the relations at right- and oblique-angled frame corners; there are likewise matrixes showing the elastic behavior of massless members restraining any points. Introduction of end conditions at simply closed (doubly connected) frames and the condition of transition at the arbitrarily chosen starting point results in a determinant with an eigenfrequency, i.e., vanishing of the determinant leads to the desired frequency. Three stiff members carrying masses, and connected at one point, give nine conditions necessary to derive determinant for threefold connected frames.

Solutions of considerable but clear numerical calculations are facilitated by means of modern computers.

W. Mudrak, Austria

3516. **Wehrli, C., Critical speed of shafts with short bearings under the influence of conservative torsion** (in German), *ETH Zürich Prom.* 2566, 43 pp., 1956.

Author investigates the critical rotational velocities of twisted shafts with short bearings, which allow an inclined position of the elastic line. The torsion momentum induced by such a bearing is represented by a rotating pair of forces, whereas the momentum at the disk is supposed to be represented either by a uniform distribution of more than two peripheral forces of equal quantity or is assumed as a steady pair of forces. With restriction to cylindric shafts of equal rigidity to bending, to one disk, and to loads which are small in comparison to the critical static bending load, the stability is investigated for six cases (one end of the elastic line either clamped or not, combined with the unloaded disk or both the cited cases of load). The mathematical formulation gives two ordinary differential equations with periodical coefficients; the well-known discussion of the Hill determinant gives the critical rotational velocity for small values of the torsion momentum. This method assumes a damping proportional to the speed. As author points out, the internal damping, however, cannot be considered by this simple assumption for the damping.

M. Schaefer, Germany

3517. **Broadbent, H. R., Forces on a brake block and brake chatter,** Instn. Mech. Engrs. Prep., 13 pp., 1955, published 1956.

An analysis of the forces on brake shoes of a passenger car "clasp-brake" arrangement under dynamic conditions is given. The analysis indicates that friction characteristics of cast-iron shoes together with clearances between pins and bushings in the brake rigging lead to brake chatter. Experimental measurements are given which verify the general conclusions of the analysis. Reviewer feels it would be helpful to present the details of the solution of the dynamic equations, which have been omitted for brevity. W. H. Sparing, USA

3518. **McGoldrick, R. T., Calculations for hull vibration of the SS Gopher Mariner and comparison with experimental results,** *David W. Taylor Mod. Basin Rep.* 1022, 27 pp., May 1956.

3519. **Reid, T. J., Free vibration and hysteretic damping,** *J. roy. aero. Soc.* **60**, 544, p. 283 (Technical Notes), Apr. 1956.

3520. **Vane, F. F., The TMB midget vibration generator and applications,** *David W. Taylor Mod. Basin Rep.* 936, 25 pp., Aug. 1955.

The TMB midget vibration generator was designed to excite forced vibrations of equipment weighing up to about 4000 lb, especially resiliently mounted equipment. The vibration generator is portable and weighs 12 lb; the control unit weighs 25 lb. The vibration generator has a speed range of 3.3 to 156.7 rps (200 to 9400 rpm). This apparatus was constructed so that it could be fastened easily to structures to be excited. Force-frequency curves are given for the various sets of eccentric weights. The various uses of the vibration generator are indicated, and procedures for correcting experimental data are given. Certain of the uses and the corrections apply for all mechanical vibration generators. From author's summary

Wave Motion in Solids, Impact

3521. **Synge, J. L., Elastic waves in anisotropic media,** *Nat. Bur. Stands. Rep.* 4601, 24 pp., Apr. 1956.

Author considers problem of plane elastic waves in homogeneous anisotropic media (21—constant elastic theory). In tensor notation, some general results are given. Special results are derived for a layer of anisotropic material of thickness h, free on one surface and excited by stress waves on the other. Resonance conditions are examined. Rayleigh waves in an anisotropic half space are considered by letting $h \longrightarrow \infty$. Author observes that, in general, the surface waves either do not exist at all or are propagated in certain discrete directions with certain speeds. Some general remarks on media possessing transverse isotropy conclude the paper. For body waves, results agree with those of Musgrave [*Proc. roy. Soc. Lond.* (*A*) **226**, 339-366, 1954]. Reviewer believes paper is interesting contribution to theory of elastic waves in anisotropic media. A. P. Boresi, USA

3522. **Nagase, M., Diffraction of elastic waves by a spherical surface,** *J. phys. Soc. Japan* **11**, 3, 279-301, Mar. 1956.

Author treats the problem of wave propagation in an infinite elastic medium enclosing a large spherical cavity (radius r_0) and containing an internal source (at $r_s > r_0$). Problem is formulated on the basis of symmetry with respect to the polar axis joining the sphere center and source. The resulting governing equations are the three separated wave equations in the dependent variables Φ, A_φ, and d_φ, respectively the scalar potential of the displacement field, the φ-component of the vector potential, and the φ-component of the displacement itself. Waves of any kind are shown to be linear combinations of Φ, A_φ and d_φ. Incident waves therefore fit into three types corresponding to these quantities, i.e., one of dilatational and two of distortional character.

Initial waves Φ, A_φ, and d_φ are taken to be of monochromatic dipole character. Series solutions involving Bessel and Legendre functions are transformed into more rapidly convergent ones with the aid of residue theory, permitting the author to make a detailed study of the various waves generated when a particular source wave reaches the surface.

Paper will be of primary interest in theoretical seismology. On the other hand the elasticity problem involved, and its interesting mathematical treatment, should command a larger audience.

J. Miklowitz, USA

3523. Eason, G., Fulton, J., and Sneddon, I. N., The generation of waves in an infinite elastic solid by variable body forces, *Phil. Trans. roy. Soc. Lond. (A)* **248**, 955, 575–607, Mar. 1956.

Fourier transforms frequently used to find the solutions of equations of motion are applied in this problem when the body forces depend also on time. Then four-dimensional transforms are required. Writing the equations of motion and stress-strain relations in the form

$$\tau^{pq}_{q} + \rho F^{p} = \rho c^{2} (\partial^{2} v^{p} / \partial \tau^{2}) \quad ; \quad \tau^{pq} = 1/2\, E^{pqrs} (v_{\tau,s} + v_{s,\tau})$$

authors assume that E^{pqrs} are factors independent of x_p (p = 1,2,3) and time $t = \tau/c$. Using the notation

$$\bar{\phi}(\xi_1, \xi_2, \xi_3 \omega) = (1/4\pi^2) \int_{E_4} \phi(x_1, x_2, x_3, \tau) \exp \{i(x_p \xi_p + \omega\tau)\}\, dV$$

where $dV = dx_1\, dx_2\, dx_3\, d\tau$ and E_4 is the entire $x_1 x_2 x_2 \tau$-space, the set of equations $\alpha^{ps} \bar{V}_s = \rho \bar{F}^{p}$, where $\alpha^{ps} = E^{pqrs} \xi_q \xi_\tau = \rho c^2 \omega^2 \delta^{ps}$ and δ^{ps} is the Kronecker delta, is readily obtained. The Fourier transforms v_s are solutions of this set of algebraic equations. Inversion of these solutions yields the components of the displacement vector (v^p) in terms of variable body forces. Simpler expressions are found for $F^p = G^p(x_1, x_2, x_3)/\rho$, for an isotropic solid, in two-dimensional problems and in the case of axial symmetry. Examples of periodic and impulsive "point forces," stationary or moving with uniform velocity, are discussed. Also considered is the effect of a circular disk of pressure moving with uniform velocity in the direction in which it acts.

W. S. Jardetzky, USA

3524. Knopoff, L., Diffraction of elastic waves, *J. acoust. Soc. Amer.* **28**, 2, 217–229, Mar. 1956.

Differential equations of elastodynamics are integrated in the form of surface and volume integrals of retarded potentials. The solutions are then used to study diffraction of elastic waves through apertures. Due to difference in propagation speeds of compression and shear waves, complicated interaction results. A pure incident wave is usually diffracted into two component waves. The distribution of primary component (same wave as incident) follows ordinary Fraunhofer pattern, while the distribution of secondary component is usually "extraordinary."

The analysis follows essentially that of Kirchhoff theory of optical diffraction except that it is complicated by interaction. The results are important for seismic study.

H. S. Tan, USA

3525. Christie, D. G., Reflection of elastic waves from a free boundary, *Phil. Mag.* (7) **46**, 376, 527–541, May 1955.

The solution of the problem of the reflection of plane elastic waves at a free, plane surface, when the wave fronts are infinite in extent, has been known for a considerable time. More recently, there has been a revival of interest in the subject as a whole and, in particular, the question of the reflection of elastic waves at grazing incidence has been discussed by a number of authors. Under these conditions, the wave front is not infinite in extent and the problem, strictly speaking, is one of diffraction. Roesler [title source, **46**, 517–526, May 1955] has, however, shown that the solution can be given in terms of reflection theory if certain variables are chosen suitably.

Author investigates the reflection of plane waves in a thin plate of Perspex when the waves fall on a free edge at angles of incidence varying between 0 and 90°. First he shows how the relationship for a semi-infinite medium must be modified to apply to the case of a thin plate (plane stress conditions). He then describes how plane waves can be produced using detonating fuse and how the waves may be observed photoelastically by a sequence of instantaneous photographs taken at intervals which can be varied between 5 and 50 μ sec. The interpretation of the photographs is discussed at length and the results are shown to agree with theory, within the limits of experimental error, over the whole range of angles of incidence.

This paper is important, partly because of the photoelastic analysis of the photographs and partly because it appears to be the first to give such a direct verification of the classical reflection relationships over a wide range of angles of incidence.

R. M. Davies, Wales

Elasticity Theory

(See also Revs. 3521, 3547, 3548, 3555, 3559, 3562, 3563, 3567, 3569, 3570, 3574, 3579, 3582, 3623)

3526. Adkins, J. E., Associated problems in two-dimensional elasticity, *J. Mech. Phys. Solids* **4**, 3, 199–205, May 1956.

If the solution of a boundary-value problem in two-dimensional elasticity is expressed in terms of complex potential functions, the expressions for the displacement at a point and the resultant force on a curve assume analytically similar forms. Author then succeeds in formulating a single parametric function for the solutions of a group of associated problems, whose boundary displacements or boundary stresses can be specified by assigning specific values to the parameters. The procedure is illustrated by the examples of a circular ring and of an infinite plate containing a circular hole. The solutions are then compared with the known results obtained by other investigators.

Reviewer considers it a notable contribution toward the generalization of solutions in two-dimensional elasticity.

D. H. Cheng, USA

3527. Finzi, L., Principle of minimum differential elastic energy (in Italian), *Atti Accad. naz. Lincei R. C. Sci. Fis. Mat. Nat.* **8**, 18, 274–280, 1955.

It is well known in the theory of elasticity that the principle of minimum strain energy is equivalent to the equations of equilibrium and the principle of complementary energy is equivalent to the equations of compatibility. Author discusses the corresponding relations for a continuum the mechanical behavior of which is specified by a relation between the infinitesimal increments of stress and strain that need not be linear and homogeneous. Such a differential stress-strain law is called holonomic if it can be integrated leading to a finite relation between stress and strain; otherwise the stress-strain law is called nonholonomic. (The terms "total" and "incremental" are used in the current English literature on plasticity to distinguish these two types of law.) For materials with differential stress-strain laws, principles of minimum differential energy are established. As the corresponding finite principles of the theory of elasticity, these principles are equivalent to the equations of equilibrium or compatibility. The relation between these principles and certain variational principles of the theory of plasticity (Hill, Greenberg) is discussed.

W. Prager, USA

3528. Capriz, G., Saint Venant problem of elastic but incompressible solids (in Italian), *R. C. Mat. appl.* (5) **13**, 3/4, 495–506, July-Dec. 1955.

Stress components for combined torsion, flexure, and axial loading of a prismatic bar are obtained in terms of two harmonic functions, the classical modified stress functions for torsion and flexure. Formulas apply either to incompressible or compressible material by suitable choice of one constant.

L. Malvern, USA

3529. Diatlovitskiĭ, L. I., Reduction of a plane problem of theory of elasticity with body forces to a boundary problem with arbitrarily distributed body forces (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 21, 43–60, 1955.

This problem has been previously solved for body weight and other body forces having a potential. Solution offered is applicable to any type of body forces. Prescribed body forces are first applied in a region for which stress distribution σ^{π} due to that type of loading is either known or computable. A portion of that region identical with the investigated shape is cut out and its boundary forces computed. The latter are then applied, with opposite signs, to the same shape and put in equilibrium by the originally given reactions. Resultant stress distribution σ^{k} is obtained either analytically or numerically. Final stress $\sigma = \sigma^{\pi} + \sigma^{k}$.

σ^{π} values caused by a concentrated load $P_y = 1$ applied to an infinite region are given in form of influence coefficients ψ. Double integration of these gives σ^{π} for any distributed loading. Fully worked out numerical example is shown.

J. Solvey, Australia

3530. Brock, J. S., The mean stress around a small opening of any shape in a uniformly loaded plate, *J. appl. Mech.* **32,** 2, 314–315 (Brief Notes), June 1956.

Proof is given of a theorem stating that the mean stress along the tree boundary of an opening of any shape in a uniformly loaded plate equals the sum of the mutually perpendicular normal stresses in remote regions of the plate. Using Green's theorem with a general curvilinear orthogonal coordinate system and the fact that the sum of the normal stresses satisfies Laplace's equation, the proposition is proved. Several particular loading conditions are considered and found to confirm the theorem. It is suggested that the theorem may be used for checking new solutions for the stresses around openings.

R. Heiser, USA

3531. Mitchell, L. H., Stress concentrations at the corners of a trapezoidal plate, *Aero. Res. Labs., Melbourne, Austral. Rep.* SM. 232, 12pp. + 5 figs., Sept. 1955.

An attempt is made to explain the discrepancies between calculated [Mansfield, E. H. "Stress concentration at a cut-out in a swept wing," *Aero Res. Counc.* Rep. Mem. 2823] and measured stresses [Coiley, G. M., AMR **8,** Rev. 603] at the obtuse angles of trapezoidal plates. A stress singularity at the corner similar to the one reported by Williams [AMR **6,** Rev. 2186] is suspected and its presence confirmed by comparing calculated results with values obtained by relaxation. Author concludes: "The problem of deciding when a singularity occurs in a given problem is difficult, but it would be interesting if the method suggested here for determining the constant A could be proved correct." The reviewer concurs.

G. Sved, S. Australia

3532. Cadambe, V., and Tewari, S. G., Application of electrical analogy for the solution of problems in elasticity, *J. sci. indust. Res., India* **15B,** 3, 107–111, Mar. 1956.

The basic theory underlying use of measured potential distribution enabling electric analog solution of a problem determined by solution of Laplace's equation over a plane area subject to prescribed boundary conditions is outlined. The design of an electrolytic tank and 600-cps electronic accessories for such measurements are described. The correctness of the theory and the use and possible accuracy of the experimental apparatus are illustrated by analog determination of the shear stresses along the vertical line of symmetry of a cylindrical shaft of equilateral triangular cross section subjected to a bending moment. The results thus obtained are in excellent agreement with corresponding results obtained analytically by Timoshenko.

T. J. Higgins, USA

3533. Morgan, A. J. A., Stress distributions within solids bounded by one or two cones, *ZAMP* **7,** 2, 130–145, 1956.

The formal solution of the equations of linear, isotropic, homogeneous elasticity is obtained for a class of statical, axially symmetric problems. The problems concern semi-infinite regions bounded by two concentric, co-axial conical surfaces subjected to arbitrarily prescribed distributions of stress. The general solution, expressed in terms of a biharmonic stress function, is obtained through the use of Mellin transform techniques. The determination of the displacements is not explicitly discussed. Specialization is made to the case of a semi-infinite solid bounded by a plane surface, and some results for the problem of a uniformly loaded circular area are recovered. The present analysis extends previous work by the same author [A.J.A. Morgan, *ZAMP* **5,** 4, 330–341, 1954], and is cognate to work by C. J. Tranter [AMR **2,** Rev. 1599] on wedge problems. It should now be possible to solve without undue difficulty a number of interesting elastic problems, hitherto unsolved and falling within the present class, particularly those for solid cones.

H. G. Hopkins, England

3534. Andreeva, L. E., Calculations concerning corrugated diaphragms, considering them as anisotropic plates (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **21,** 128–141, 1955.

Paper deals with approximate calculation of corrugated diaphragms. With the aid of two axial planes and two cylindrical surfaces, author cuts out of the body of the diaphragm an element of definite dimensions. This element is subjected to tension and bending in the direction of the radius, as well as in the direction of the tangent. Tension- and bending-rigidity in the direction of the radius are here different than those in the direction of the circumference of the circle. Owing to this circumstance, the diaphragm resembles a circular anisotropic plate and is here discussed as such. The rigidities of the anisotropic plate are determined as corresponding to the rigidities of a corrugated diaphragm. The rigidities having been determined, the amounts of deflection of the plate are calculated on the basis of large displacements.

Author deals with various types of corrugated diaphragms, quotes a number of examples, and gives several diagrams of diaphragm properties. Comparison of the result obtained with experiments demonstrates satisfactory concordance.

W. Wierzbicki, Poland

3535. Beer, H., A structural statical method for the calculation of orthotropic plates and grids (in German), *Öst. Ing.-Arch,* **9,** 2/3, 78–85, 1955.

The orthotropic, torsion-resistant plate is decomposed into two series of beams intersecting each other at right angles, each beam being loaded by a fictive load portion which is assumed to cause the same statical effect in the beam that results in the corresponding strip of the orthotropic plate. This load-distribution method enables one to compute, with an accuracy sufficient for practical purposes, the sectional forces and the deflections occurring in the plate, with full consideration of its torsional rigidity.

In this paper the method is applied to the rectangular plate supported freely on its boundaries, and is explained for various types of loading. An application to the elastically clamped plate will be given in another paper.

From author's summary by C. B. Biezeno, Holland

3536. Nowiński, J., and Turski, S., On the theory of elasticity of isotropic nonhomogeneous bodies (in Polish), *Arch. Mech. stos.* **5,** 1, 67–87, 1953.

Authors present a study on the foundations of the theory of isotropic nonhomogeneous bodies. It is characterized by two variable elastic coefficients: Young's modulus E and Poisson's ratio ν. It is assumed that these coefficients are functions (with an adequate degree of regularity) of the coordinates of the considered

point of the elastic body. To simplify the calculations the equations are derived with the assumption that only Young's modulus is variable: $E = E(x, y, z)$. The Lamé equations for displacement components, as well as the Beltrami-Michell equations for stress components and the basic equation of M.Lévy for the plane problem, are derived.

The following problems are solved to illustrate the applications of the theory: longitudinal vibrations of a nonhomogeneous bar; torsion of a circular bar, assuming that the shear modulus G is a function of the distance from the axis to the bar only; the problem of Lamé for a thick-walled tube if the coefficient E is a function of the distance from the axis to the tube only; the Filon-Ribière problem for a rectangular strip subjected to bending in its plane if Young's modulus is constant for each longitudinal fiber and different for different fibers.

The results constitute a natural generalization of the foundations of the classical theory of elasticity to isotropic homogeneous bodies. T. Iwiński, Poland

3537. Kaczkowski, Z., Conjugate directions in an anisotropic body (in German), *Bull. Acad. Polonaise Sci.* (IV) **3**, 3, 125-127, 1955.

The stress equations of equilibrium, strain-displacement relations, and the generalized Hooke's law are referred to a set of rectilinear skew coordinates. Author then defines "conjugate directions", in a body which is orthotropic with respect to a set of orthogonal axes, as orientations of the skew coordinate axes for which the number of independent elastic constants, referred to the skew system, is reduced. Unfortunately, author neglects to show just how such directions are to be found, or, indeed, what are the circumstances under which they exist.

H. Deresiewicz, USA

3538. Litwińiszyn, J., On a type of heterogeneity of continuous media of elastic bodies (in Polish), *Arch. Mech. stos.* **7**, 3, 301-314, 1955.

In this paper the notion of heterogeneity of a continuous medium with finite deformations is analyzed. The motion of such a medium is considered as a motion of individualized particles of a continuous medium with respect to the immovable Cartesian coordinates system. To simplify considerations, author investigates a medium with one variable Cartesian coordinate and introduces one Lagrangian coordinate, determining individual particle of the medium. Material constants depend upon the Lagrangian coordinate and upon the time. It results that Lagrangian coordinates are to be introduced into the considerations. All constants are of the "density" type, as they may be transformed, when changing Lagrangian coordinates into Cartesian ones, in the same manner as densities.

Author introduces the ideas of spatial, temporal, and temporal-spatial heterogeneity, as well as constant with time (called natural) and acquired heterogeneity, i.e., depending upon history of a particle of the body, when the latter has a "memory."

Furthermore, a general equation of motion for one-dimensional rheologic body is derived in terms of Lagrangian coordinates.

In the most simple case of longitudinal vibration of a string of "natural" heterogeneity, a quasi-linear equation is obtained, in consequence of the density type of the elasticity constants.

In applying the presented theory, creep problems and examples of some particular linearly heterogeneous rheologic bodies are considered. J. Naleszkiewicz, Poland

3539. Olszak, W., and Urbanowski, W., A heterogeneous thick-walled elastic-plastic cylinder subjected to internal pressure and longitudinal force (in Polish), *Arch. Mech. stos.* **7**, 3, 315-336, 1955.

The elastic-plastic solution of the problem in respect to homogeneous bodies has been known for a long time. By generalizing existing solutions authors deal with heterogeneous (elastically and plastically) but isotropic systems. Elastic and plastic properties are assumed to be functions of the radius only; this means that heterogeneity is axially symmetrical. Also, plane strain in the section perpendicular to the axis of the cylinder is assumed. By introducing two auxiliary functions, a system of differential equations for heterogeneous elastic state has been obtained; these equations have been integrated for incompressible bodies ($\nu = 1/2$) and a solution for plastic region has been found. A heterogeneity was assumed which makes possible the co-existence of inner plastic and outer elastic region. By assuming a load consisting of monotonically increasing internal pressure (of the "simple" type, in the sense of A.A.Ilyushin), a solution is found for the ideal plastic state, in which the value of the invarient J_2 of the stress deviator is the same at each point of the body (varying, however, from point to point, depending on the radius), elastic heterogeneity being independent from plastic heterogeneity. There are two well-known critical pressures: one of them corresponds to the beginning of yielding on the inner surface; the second one to the plastic state of the whole cylinder.

Furthermore, authors analyze the conditions which must be satisfied by the heterogeneity of the material in order to provoke simultaneous yielding of the whole cylinder, i.e., to prevent the occurence of intermediate stages. In the authors' opinion, a material exhibiting such properties gives maximum economy. Finally, an example of conjugated plastic and elastic heterogeneity of the material is given. J. Naleszkiewicz, Poland

3540. Urbanowski, W., Elastic-plastic deformation of a thick-walled spherical vessel subjected to internal pressure (in Polish), *Arch. Mech. stos.* **7**, 4, 519-532, 1955.

Purpose of the paper is to determine stress and strain distribution in a thick-walled spherical vessel subjected to internal pressure. The material of the vessel is assumed to be isotropic and homogeneous and to exhibit linear strain-hardening. The elastic compressibility of the material is the same in all ranges.

Three spherical regions are to be discerned in the vessel subjected to a load. In the inner region there is a range of "plastic consolidation" (strain-hardening); in the middle one, an ideally plastic range; in the outer one, an elastic state. Such a triple state of stress is possible only when the walls are thick. In the case of thinner walls there can exist two regions only. The case of a material which does not exhibit plastic platform when passing the yield point is also considered. The results obtained agree with results given by other authors.

Furthermore, author determines the variations of stress and strain fields during unloading, i.e., when pressure decreases after reaching its maximum value. This method enables determining the residual stresses in the vessel when the internal pressure has ceased. J. Naleszkiewicz, Poland

3541. Hazony (Hasanovitsh), D., Deflection of inelastic columns, *J. aero. Sci.* **23**, 4, 390-391 (Readers' Forum), Apr. 1956.

The author shows how to obtain, approximately, a known differential equation for the deflection of an inelastic column in which the material obeys a parabolic stress-strain relationship beyond a specified value of stress and linear stress-strain relationship up to the specified value. D. N. Mitra, India

3542. Raymondi, C., Analysis of arches combined with girders (in Italian), *G. Gen. civ.* **93**, 9, 520-536, Sept. 1955.

Combination of arches with supported girders is especially typical for bridges. In many cases, the flexibility of the arches can seriously affect the continuous roadway girders, and the combined structure, as continuous girders on elastic supports, becomes highly statically indeterminate and more complicated. Paper presents simplified analysis of both typical schemes of supports, either with columns or hangers, assuming the bending moments in

the arch at the supported sections as redundant values and the sections between supports as straight and with constant moment of inertia. Elastic equations are derived for the scheme with arch and girder having hinged end supports, and also for the case where these ends are rigidly restrained. Also equations of influence lines for hyperstatic values are derived. Analytic procedure is demonstrated on an example of a two-hinge arch bridge spanning 42 m (137 ft) with relatively slender spandrel columns supporting heavy girders. No reference is given to similar subjects.

J. J. Polivka, USA

3543. Rutecki, J., Torsion of thin-walled conical tubes with constant wall thickness (in Polish), *Arch. Mech. stos.* **7**, 2, 231-246, 1955.

Paper is devoted to the problem of torsion of constrained thin-walled conical tubes with open cross section and constant wall thickness. Assuming that the cross sections of the tube are rigid in their planes and that there is no shearing strain in the middle plane of the walls, author derives the following differential equation for the angle of twist φ:

$$\eta^4\varphi^{(IV)} - k^2\varphi'' = m_s l_c^5/ET_{w_r}\eta \qquad [1]$$

Here η denotes the coordinate measured along the generator, l_c total length of the generator, m_s intensity of the torsional moments, E modulus of the elasticity, T_{w_r} a quantity proportional to the "sectorial" moment of inertia of the fixed cross section of the tube, k^2 a constant depending upon dimensions of the tube and elastic properties of the material.

A rigorous solution of the homogeneous equation corresponding to [1] as well as an approximate solution by the Galerkin method are given. In the latter case, a simple formula suitable for engineering practice has been obtained.

The results of the theory have been verified by experiments and show satisfactory agreement. J. Leyko, Poland

3544. Ivković, M., The deformation of a hollow cylinder of infinite length loaded by a rotary symmetrical load on a finite length (in Serbian), *Acad. Serb. Sci. Publ. Inst. Hydrotech.* "Jaroslav Cerni" **38**, 2, 123-144, 1954.

The biharmonic differential equation for the stress function of an elastic body with axial symmetry is solved by an infinite sum of products which contain factors of the form $\sin kz$ with z as coordinate along the axis. The other kind of factors are linear combinations of $K_0(kr)$ and $r_0K_1(kr)$, where K_0 and K_1 are modified Bessel functions of second kind and of order zero and one, respectively. General expressions for stress components can be then established in explicit form and the constants can be determined through the boundary conditions on the inner surface of the hollow cylinder if the sum in the expression for the radial stress component is changed into an integral and compared with the external load. When the stress components are known, the components of displacement can be determined by quadratures. Theoretical results are applied to the case of uniform load over a part of the cylinder, and, in a numerical example, the computed values of radial displacements are compared with those obtained by experiment. The agreement, especially in the middle part of the loaded cylinder, is good. A. Kuhelj, Yugoslavia

3545. Hingorani, N. V., Stresses in chimneys due to temperature, *Concr. constr. Engng.* **51**, 7, 425-434, July 1956.

3546. Druyvesteyn, M. J., and Berghout, C. W., Influence of an elastic strain on the self-diffusion of copper at low temperatures, *Phys. Rev.* (2) **102**, 6,p.1686 (Letters to the Editor), June 1956.

Experimental Stress Analysis

(See also Revs. 3526, 3594, 3752)

3547. Allen, D. N. de G., Chitty, L., Pippard, A. J. S., and Severn, A. T., The experimental and mathematical analysis of arch dams, with special reference to Dokan, *Proc. Instn. civ. Engrs.* **5**, (I) 3, 198-258, May 1956.

Paper presents description of elastic analysis of arch dams by the method of relaxation, applied to Dokan dam in Iraq. This was the first application of the method to a structure of this type and magnitude (516 meters high), and it took, together with preliminary computations, over three years. Separate calculations were made for the effects of gravity, water pressure, and temperature, the first considering the structure divided by construction joints into independent cantilevers, and the other two on the assumption of complete continuity. The computed displacements were compared with the measurements on a rubber model made to a scale of 1 to 253.

The method used consisted in setting up three partial differential equations of equilibrium of an element of the dam, expressed in terms of three components of displacements, using cylindrical coordinates, since the vertical upstream face of the dam was cylindrical. The six stress components were also expressed in terms of the derivatives of the displacements. A three-dimensional mesh was then inscribed in the dam, and the differential equations of equilibrium and the expressions for stresses were replaced by the difference equations and expressions in terms of the displacements of the nodal points. In order to satisfy the boundary conditions on the surfaces of the dam, fictitious nodes were set outside of the dam. The values of their displacements were such that they satisfied the stress conditions at the boundary.

The process of solution consisted in assuming some appropriate values of the displacements at all nodes, substituting them into the difference equations of equilibrium, finding the amounts of unbalance in the equations, and then modifying the displacements one by one so as to remove the unbalances. Even allowing for approximate symmetry of the dam the procedure was bound to be very lengthy in view of the presence of some 350 nodes with three displacements each. After all unbalances were reduced to sufficiently low values, the stress components were determined at all nodes by the difference expressions.

As might be expected, the stresses caused by the gravity action on independent cantilevers agreed closely with the ones found by the elementary theory. Of much greater interest, however, was the calculation of the water pressure action. In this case, after allowing for the scale ratio and the difference in the moduli of elasticity, the displacements obtained by the relaxation and the model analysis did not agree in view of the different values of the Poisson's ratio, which was 0.5 in rubber model and was assumed 0.15 in the relaxation. However, it was possible to deduce from rational considerations a reduction coefficient for effective modulus of elasticity of the model, using which a reasonable agreement was obtained in radial and tangential (but not the vertical) displacements.

Reviewer considers the described method as an outstanding contribution to solution of the extremely important and at the same time highly complex problem of the elastic analysis of arch dams. It appears to him more realistic than the trial load method of U. S. Bureau of Reclamation, which visualizes the more or less equidimensional block of concrete of the dam as a combination of arches and cantilevers.

The principal defect of the relaxation method is the staggering amount of computation labor, with only one computer at a time, which so far has not been overcome by the use of mechanical computers. Then a question arises about the accuracy of the solution. There is an error involved in replacement of the differential equations which is greater the bigger the size of the mesh in relation to dimensions of the structure. The thickness of the dam at the

top is only one mesh unit and, at the point of the greatest stress, less than two units. Further error is brought in when expressing stresses as derivatives of the displacements in the presence of remaining minor unbalances in the difference equations. The model study unfortunately cannot be used for appraisal of the extent of these errors. A. Hrennikoff, Canada

3548. Chitty, L., and Pippard, A. J. S., The determination of the stresses in an arch dam from a rubber model, *Proc. Instn. civ. Engrs.* **5,** (I) 3, 259–275, May 1956.

This paper, based on the work presented in the previous paper, describes attempts to devise a workable method of design of arch dams on the basis of measurements of displacements on the rubber model. The difference in values of the Poisson's ratio for rubber (0.5) and concrete (0.15) gave rise to some difficulties. However, it was possible to deduce from rational considerations a reduction coefficient for the modulus of elasticity, using which, and making proper allowance for the scale ratio and the ratio of moduli of elasticity of the dam and the model, some reasonably close agreement was found in the radial and tangential displacements, but not in the vertical ones. This condition precluded the use of vertical displacements on the model for calculation of stresses on the prototype.

The design problem, set up by the authors, was limited to determination of stresses on the central plane of the dam where they were the greatest. The elementary bending theory was quite accurate for finding the vertical stresses caused by gravity, in view of construction of the dam in the form of separate vertical cantilever blocks, grouted together later.

In considering the effect of water pressure, the vertical stresses were found by the elementary bending theory, integrating twice the curve of radial displacements on the central cantilever, obtained by fitting the observed values of the displacements into a polynomial and determining the coefficients of the latter by least squares, which procedure had a smoothing effect on the curve. The vertical stresses so found checked fairly well with the values determined by relaxation, but the comparison unfortunately was presented only after combining these stresses with the ones caused by gravity.

The design hoop stresses, also on the central line of the dam, were found from an expression based on differential equations for stresses in terms of the derivatives of the radial and tangential displacements. Some approximations were introduced. The agreement with relaxation was good. Some other methods discussed in the paper were speculative. A. Hrennikoff, Canada

3549. Ockleston, A. J., Loading tests on the floor systems of a reinforced concrete building, *Trans. S. African Instn. civ. Engrs.* **6,** 2, 61–69, Feb. 1956.

Paper briefly summarizes the results of loading tests on the floor systems of a reinforced-concrete building of normal construction which had been in service for about 10 years.

Within the range of working loads, the observed deflections and strains were almost always less than those corresponding to the design assumptions.

The failing loads exceeded those given by both elastic and plastic theories, but were in closer agreement with the latter.

From author's summary by R. K. Bernhard, USA

3550. Little, G., The distribution of a load in a box-section bridge from tests on a xylonite model, *Mag. Concr. Res.* **6,** 18, 121–132, Dec. 1954.

A small model of a box-beam bridge was tested for its load-distribution properties. The distribution was determined experimentally by deflection and strain readings.

The material used in the construction of the model was Xylonite, a cellulose-base material of Young's modulus 33.33×10^4 lb/sq in. and modulus of rigidity 11.7×10^4 lb/sq in.

The experimental distribution of deflections and longitudinal bending moments proved to be in close agreement with the distribution given by a theoretical treatment involving distribution factors. The distribution patterns were found to be virtually unaffected by changes in the longitudinal position of the load.

On the other hand, there were large discrepancies between the experimental and theoretical transverse bending moments. The discrepancies were almost certainly due in part to the small absolute values of the bending moments, which were only about 40% of the corresponding longitudinal moments, and to their high rate of variation across the transverse section both in magnitude and sense. Nevertheless, it was confirmed that the maximum transverse moment occurs at the center of the bridge when the load is at its position of minimum eccentricity. Further investigation into the distribution of transverse moments will be made on suitably designed models. From author's summary

3551. Gabrielli, G., Theory and application of structural models for aeronautical design (in Italian), *J. Flugwiss.* **4,** 5/6, 198–202, May/June 1956.

Author premises that the use of structural models and the transfer of results of elasticity or failure tests from the models to the actual aircraft have not yet found sufficient application and appreciation in aeronautics, and he hopes for wider use of them.

After pointing out the significance of the principal coefficients or factors adopted to determine loads on aeronautical structures, author enunciates, in its most general form, the law of structural similarity. Referring finally to his publications dated back to 1928, he supports the great usefulness of Herbert Wagner's diagram which permits an evaluation of the behavior of structures, with regard to local yields having different natures and origins, and permits also an evaluation of the form of the section and of the more suitable materials to be employed in the most diverse cases. In this diagram the so-called index of structural load appears on the abscissa. Various authors, such as N. A. de Bruyne and E. D. Keen, have extended the use of this index to several particular cases. The index of structural load is, in fact, a constant for every given structure and expresses the law of structural similarity applied to the limit of proportionality, or to failure, or to whatever other degree of load. From author's summary

Rods, Beams, Cables, Machine Elements

(See also Revs. 3507, 3516, 3528, 3532, 3535, 3541, 3569, 3571, 3573, 3579, 3581, 3596)

3552. Johnson, W., The twist due to bending moment in cantilevers curved in plan, *J. roy. aero. Soc.* **60,** 544, 277–281 (Technical Notes), Apr. 1956.

Paper refers to cases in which the cantilever carries a concentrated load at its end and investigates simple forms, as ⊏ and I sections. Elementary stress analysis is used. Nonlinear shear distribution in flanges and existence of a virtual shear center for beams curved in plan is demonstrated.

A. Selberg, Norway

3553. Rosen, B. W., Analysis of the ultimate strength and optimum proportions of multiweb wing structures, *NACA TN* 3633, 34 pp., Mar. 1956.

Structural efficiency analysis of subject structures is presented relating minimum weight to the variables—bending moment, wing chord, depth, and skin thickness—to allow comparison of structures of different materials or construction so designed as to fail by local buckling and to eliminate failure by wrinkling between

attachments. Experimental data are presented to substantiate assumptions concerning web behavior and skin strength. No consideration is given to web shear, factors of safety for practical design, or limitations imposed by vibratory or aeroelastic effects. Results are presented in form of efficiency charts relating bending strength to a structural index based on beam proportions and material properties. G. P. Fisher, USA

3554. **Iwiński, T., Discontinuous solutions of the equations of structural mechanics obtained by means of the Laplace transformation and illustrated by the example of a beam of sectionally constant rigidity** (in Polish), *Arch. Mech. stos.* **7**, 3, 404–418, 1955.

The fundamental relation

$$L[f^{n}(x)] = s^{n}L[f(x)] - \sum_{k=0}^{n-1} s^{n-k-1} f^{(k)}(0) \qquad [1]$$

$$(L[f(x)] \equiv \int_{0}^{\infty} e^{-sx} f(x)dx)$$

on which applications of the Laplace transformation for solving differential equations are based, may be extended to cover the case when $f(x)$, $f^{1}(x), \ldots, f^{(n)}(x)$ are functions sectionally continuous. The formula [1] includes, in this case, additional terms, depending upon the values of "jumps" of the functions $f(x)$, $f^{1}(x), \ldots, f^{(n-1)}(x)$ at their points of discontinuity. The above values form a set of, so to say, additional boundary conditions, the knowledge of which is needed to determine the solution.

In this paper, the generalized formula [1] is used to solve problems of bending of beams of sectionally constant rigidity, subjected to arbitrary vertical load. The values of jumps of the deflection function and its derivatives are determined by geometrical and physical conditions of the problem (e.g., jumps of $y(x)$ are encountered at the points where dimensions of beam cross sections vary, jumps of $y'(x)$ and $y''(x)$ at the points of application of concentrated moments and forces, etc.).

When the points of discontinuity of the functions $y(x), \ldots, y''(x)$ and the corresponding values of jumps are known, the differential equation of bending is solved by means of Laplace transformations. The solutions are given in the form of a sectionally continuous function or "stepped" function. The paper includes a numerical example. J. Osiowski, Poland

3555. **Abbassi, M. M., Torsion of circular shafts of variable diameter,** *J. appl. Mech.* **22**, 4, 530–532, Dec. 1955.

Transformation to spherical coordinates leads to a solution for the torsion stress-function in terms of Legendre associated functions of degree n and order 2. The condition that the torque be constant along the bar rules out the above functions of the second kind, leaving a general solution in terms of Legendre associated functions of the first kind of degree n and order 2. Two special cases are considered; viz., shafts with generating curves $r^{4}z = K$ and $r^{6} - 6r^{4}z^{2} = K$, where K is constant.

In the last section, the upper case Z should be lower case to conform with the notation of the remainder of the paper.
C. T. West, USA

3556. **Schade, H., Contribution to the calculation of cylindrical helical springs** (in German), *ZVDI* **98**, 4, 131–132, Feb. 1956.

This short paper establishes a simple mathematical formula to solve the particular problem of designing the helical spring of the smallest length for a given deflection and a given preload.
C. Massonnet, Belgium

Plates, Disks, Shells, Membranes

(See also Revs. 3508, 3509, 3512, 3526, 3534, 3543, 3544, 3568, 3574, 3575, 3592)

3557. **Bassali, W. A., and Dawoud, R. H., Bending of a circular plate with an eccentric circular patch symmetrically loaded with respect to its centre,** *Proc. Camb. phil. Soc.* **52**, 3, 584–598, July 1956.

The expressions of deflection, slope, and bending moment for thin, circular plates loaded in the following manner are obtained: (a) load uniformly distributed along the circumference of an eccentric circle; (b) load distributed over an eccentric circular patch, symmetrically to its center. Five different boundary conditions are considered in each problem. A table containing values of various parameters was prepared. W. Ornstein, USA

3558. **Kaczkowski, Z., On orthotropic rectangular plates with free edges** (in Polish), *Arch. Mech. stos.* **7**, 4, 457–482, 1955.

In this paper, free vibrations of an orthotropic plate resting on an elastic Winkler-type foundation and stretched with forces n_x and n_y acting in the plane of the plate are discussed. The plates considered have one or more edges free. The method of solution of the problem is shown in detail on the most simple example of vibrations of a plate with only one edge free, and is then extended to plates with more edges free. The idea consists in loading certain lines with vertical loads and bending moments, in such a manner that along given straight lines bending moments and shear forces vanish.

Representing the deflection surface and the load in the form of double trigonometric series, author arrives at an infinite system of secular equations with unknown parameter ω. The determinant of the system equal to zero gives the condition of free vibration of the plate. Then the case of a plate with all edges free and supported at the corners is treated in detail. The method of solution of ten other examples is also given.

In the second part, all the complicated series appearing in the secular equations are presented in finite form. The paper may be considered as an important contribution to the problem of free vibration of rectangular plates because solutions of several unsolved cases are obtained. W. Nowacki, Poland

3559. **Dolpher-Larsen, E., Equilibrium of a thin plate resting on a semi-infinite elastic solid,** *Bygnsstat. Medd.* **27**, 1, 21–48, Feb. 1956.

Paper contains an investigation of circular slabs on elastic foundation based on the theory of potential. Aim is to give a solution of the problem of a circular slab loaded axisymmetrically on the whole or a part of the face.

Author gives a general recapitulation of Boussinesq's classical potential theory for semi-infinite solid under surface load, of the same problem for a variable load, and of the theory of thin plates.

Equilibrium of a plate resting on elastic foundation is then discussed, and a circular slab axially loaded on a part of the face is studied in particular.

From author's summary by F. Correia de Araújo, Portugal

3560. **Mansfield, E. H., Optimum designs for reinforced circular holes,** *Aero. Res. Counc. Lond. curr. Pap.* 239, 15 pp. + 15 figs., 1956.

This is another of a series of considerations by the same author of problems concerning cutouts in plane sheets. The optimum weight-strength design of reinforced circular holes in an infinite sheet is considered theoretically. Several stress systems in the main body of the sheet are considered: uniform stress in all directions, principal stresses in the ratio 2 : 1, pure shear, uniform stress in one direction. The method of solution is an inverse one; a stress function is chosen which satisfies the compatibility

condition and the boundary conditions at infinity and gives rise to arbitrary perturbation stresses round the hole. Then, the cross-sectional area of the reinforcement is determined in terms of these arbitrary perturbation stress systems. The objective in a particular case is to determine what distribution of reinforcing material will produce the least stress concentrations, and if this optimum distribution is too heavy, what then is the optimum distribution for reinforcements of a given smaller total weight.

The method is both simple and straightforward. The results are most certainly directly applicable to design problems. Several illustrative problems are included.

J. H. Baltrukonis, USA

3561. Schmidt, K., Stresses in out-of-round tubes under internal pressure (in German), *ZVDI* **98,** 4, 121–125, Feb. 1956.

Stresses in thin tubes under internal pressure caused by the presence of out-of-roundedness in the circular cross section are determined by means of the principle of least work. Three types of out-of-roundedness are considered: sharp-cornered, oval, and flattened. For equal degree of out-of-roundedness (defined as the ratio of the difference between maximum and minimum diameters to their average value), stress is highest for the first type. Problem solved is essentially that of a two-dimensional ring.

Y.-Y. Yu, USA

3562. Olesiak, Z., The state of stress and strain in a thin-walled tube of lenticular cross section subjected to bending (in Polish), *Arch. Mech. stos.* **7,** 4, 503–518, 1955.

Paper deals with bending of a curved thin-walled elastic tube of lenticular cross section. The upper and the lower portions of the tube have different thicknesses and different radii. The radius of the curvature of the axis of the tube is large as compared with radii of the cross sections. The problem is solved by energy method, assuming displacement components in the form of linear functions. The latter assumption is similar to that of M. T. Huber, who considered a curved thin-walled tube of elliptical section.

When formulating displacement functions, circular walls of the cross sections are assumed to remain circular, and the length of the middle line of the section is assumed to be constant.

Paper gives critical analysis of Huber's aforementioned publication; it is shown that, if transversal strain is assumed to be $\epsilon_{3ent} = \epsilon_2 - \nu\epsilon_1$, then–after passing to the limit case of a straight tube–in the case of circular cross sections, formulas of the elementary theory of bending are obtained. Paper is completed by numerical example and by diagram of the reduced coefficient of rigidity for the case when radii of curvature and thicknesses of both parts of lenticular section are equal.

A. Kornecki, Poland

3563. Trostel, R., Unsteady thermal stresses in hollow cylinders of circular cross section (in German), *Ing.-Arch.* **24,** 1, 1–26, 1956.

Paper contains an extensive and valuable collection of formulas for hollow thick-walled cylinders of finite length which are subject to steady or variable axisymmetrical temperature distributions at inner and outer walls (arbitrary but constant heat-transfer coefficients are assumed) and to a somewhat simpler condition, of type $aT + b\partial T/\partial z = 0$, at the two end faces. Author first solves the problem of steady-state temperature distribution, then the problem of transient temperatures, then calculates the consequent stresses away from the end faces, then outlines the method for calculating the stresses near the end faces. Paper concludes by simplifying formulas to z-independence in temperature and applying results to special problems.

Reviewer's comments: The end problem of the solid cylinder was previously considered by F. H. Murray, "Thermal stresses and strains in a finite cylinder," 1945, Report AECD-2966, and by H. Poritsky and G. Horvay, "Discussion of the paper, 'Stresses in pipe bundles,'" AMR **5,** Rev. 1017; reading of the latter paper is not aided by the use of symbol μ both as Poisson ratio and as eigenvalue parameter.

Author sets up two eigenvalue equations for solution of end problem since he notes that disposable coefficients related to one equation are only half as many as the number of boundary conditions. Reviewer offers the point of view that the second eigenvalue equation will lead to the same results as the first, and that the belief that the number of disposable coefficients is insufficient results from an optical illusion which was clarified only very recently—for the similar but simpler problem of the rectangular strip—by R. C. T. Smith [AMR **7,** Rev. 1272] and by G. Horvay ["Biharmonic eigenvalue problem of the semi-infinite strip," *Quart. appl. Math.*, in press].

G. Horvay, USA

3564. Hoff, N. J., The accuracy of Donnell's equations, *J. appl. Mech.* **22,** 3, 329–334, Sept. 1955.

In the bending theory of cylindrical shells a set of three partial differential equations for the displacements must be solved. Different forms of these equations have appeared in the literature, among them Flügge's, which are very accurate but complicated, and Donnell's, which are much simpler but of limited applicability. Author investigates how far Donnell's equations may safely be used by comparing the solutions of the characteristic equations of both sets. He assumes that the deviations are small and thus obtains linear equations for them, which can be solved easily. It turns out that the error incurred when using Donnell's equations is less the thinner the shell, and, to some degree, the shorter the cylinder. The paper contains quantitative statements based on the generous assumption that an error of 10% is admissible.

W. Flügge, USA

3565. Fuchssteiner, W., Cylindrical shells: elementary treatment of edge disturbances (in German), *Beton u. Stahlbeton.* **50,** 5, 131–136, May 1955.

To find the stresses in a barrel-vault shell, one usually starts from a membrane solution and corrects it by superposing bending stress systems caused by loads applied along the straight edges. Although this procedure is correct, its tediousness calls for a better approach. The author offers a simplified version of Lundgren's ideas (see his book, "Cylindrical shells," vol. 1 Copenhagen 1951, p. 63). He first treats the shell including the edge members as a simple beam and applies Navier's theory. Then he finds from shell equations the corresponding distribution of the load. Its difference from the actual load is a second load applied to the shell. It is self-equilibrating in each cross section, and simple arch analysis is applied to deal with it.

W. Flügge, USA

3566. Rudiger, D., An exact theory of anisotropic prismatic shells (in German), *Ing.-Arch.* **23,** 2, 133–150, 1955.

Paper deals with so-called 'Faltwerke' shells used in concrete roof construction, in which the prismatic shell is composed of flat-plate segments. The proffered theory has each plate satisfy two-dimensional elasticity equations, the usual flat-plate bending equation, plus appropriate boundary conditions. Solution is expressed in series form which leads to a rather large set of equations to be handled. Titular anisotropy refers to plate with beam stiffeners incorporated. A few results of calculations are presented.

G. W. Housner, USA

3567. Nowiński, J., and Turski, S., Solution of the Lamé problem for a heterogeneous cylinder by means of the ARR differential equation analyzer (in Polish), *Arch. Mech. stos.* **7,** 3, 419–424, 1955.

Authors determine, by means of graphs, the circumferential stress distribution in a thick-walled tube subjected to an external hydrostatic pressure, in the case when the ratio $b:a$ (outer to inner

radius) is 2, Poisson's ratio $\nu = 1/3$, and Young's modulus varies in accordance with the law $E = E_0 r^n$ (E_0 = constant, r = radius), where $n = 0, 1, 2$. Graphs are obtained by means of the Differential Equations Analyzer ARR (Polish abbreviation) constructed by the Mathematical Institute of the Polish Academy of Sciences. It was found that, at $n = 0.85$, circumferential stress in the tube is approximately uniform. W. Urbonowski, Poland

Buckling Problems

3568. Nagel, F. E., Column instability of pressurized tubes, *J. aero Sci.* **23,** 6, 608–609 (Readers' Forum), June 1956.

The instability of a pressurized tube may be visualized by an analogy to a tube filled with balls. The allowable compressive load depends on the bending stiffness of the tube to stabilize the column formed by the balls. The tube has no axial load. An equation is derived which is identical with the Euler formula for $F = pA$. From author's summary

3569. Nylander, H., Torsion, bending, and lateral buckling of I-beams, *Trans. roy. Inst. Technol. Stockholm* no. 102, 140 pp., 1956.

Treatise deals with stability problems important in the design of thin-walled beams and columns. Treatment is comprehensive and is developed primarily for I-beams with a single axis of symmetry loaded simultaneously in torsion, bending, and compression. It is shown further that it can be generalized to apply to completely unsymmetrical thin-walled sections. The basic approach is to introduce an idealized torsional rigidity and then to study the deformation of the shear center axis.

Paper begins with an unusually lucid discussion of the distinction between shear center and center of twist. The distinction is found to be important only with finite deformations and cross sections prevented from warping. Author confines himself to infinitesimal strains and the usual assumptions of theory of elasticity. General equations for unsymmetrical beams are developed by energy methods with the simplifying assumption that bending and torsional moments are proportional to corresponding displacements. Particular solutions for a number of practically important cases of loading are then developed. Lateral buckling of continuous beams, as well as beams on two supports, beams with eccentric oblique loads, and beams with initial deflections loaded in the plane of symmetry, are among the problems discussed. Many results are given in graphical form, and comparisons of bisymmetrical with monosymmetrical beams are made. A. D. Topping, USA

3570. Hoff, N. J., Approximate analysis of the reduction in torsional rigidity and of the torsional buckling of solid wings under thermal stresses, *J. aero. Sci.* **23,** 6, 603–604 (Readers' Forum), June 1956.

Title problem is solved by energy method for thin doubly symmetrical uniform section with temperature constant spanwise and thicknesswise, but varying chordwise symmetrically. Assumption that span is large enough to insure uniform spanwise stresses except near ends leads to simple uniform twist buckled form. In addendum author notes previous derivation of results by others.
P. C. Dunne, England

3571. Braathen, B., and Noton, B. R., Comparison of theoretical and experimental results for 24S-T and 75S-T aluminium alloy columns buckling in the elastic and inelastic ranges, *Flygtekn. Försöksanst. Medd.* **66,** 31 pp., 1956.

An investigation of buckling of pin- and flat-ended columns of rectangular cross section. The tangent modulus theory appears to be the most suitable of those considered.
G. Gerard, USA

3572. Reinitzhuber, F., Buckling of straight columns with linearly varying longitudinal force in the elastic and plastic region (in German), *Bautech.-Arch.* no. 11, 1–32, 1955.

Author treats different cases of importance in civil engineering. Both elastic and plastic buckling are considered. Solutions are compared with approximate formulas according to DIN 4114. New formulas are suggested.

Differential equation for column deflection is derived by means of variational method; then buckling load by means of Galerkin's method. It is shown that first term of series expression for deflection gives results sufficiently accurate for practical purposes. In plastic region author assumes the ratio of Engesser's buckling modulus to Young's modulus to vary linearly from 1 at proof stress to 0 at yield point.

Author concludes that existing approximate formulas in DIN 4114 are sufficient for practical purposes as regards elastic buckling. For plastic buckling, however, the new formulas presented can be used with advantage. E. Steneroth, Sweden

3573. Sułocki, J., The buckling of a bar in an elastic medium (in Polish), *Arch. Mech. stos.* **7,** 4, 561–575, 1955.

Paper deals with a prismatic elastic bar with hinged ends, partially immersed in a Winkler-type elastic medium. The bar is subjected to axial compressive force. From the boundary conditions, which are satisfied by integrals of linearized differential equations of the deflection function of the bar when buckled, a transcendental equation of rather intricate form is obtained. The roots of this equation are the critical values of the load.

By using the Galerkin method, approximate solution is obtained. The results for various elastic properties of the medium and various depth of immersion of the bar in the elastic medium are shown in a table and a graph. By applying this method approximate critical values of the load are determined in the case when the modulus of the foundation is linearly variable.
Z. Kączkowski, Poland

3574. Ralston, A., On the problem of buckling of a hyperbolic paraboloidal shell loaded by its own weight, *J. Math. Phys.* **35,** 1, 53–59, Apr. 1956.

The shell is chosen so that its four edges are straight lines. The edges are assumed to be members that are rigid in the direction of their axes, have negligible bending resistance in planes tangent to the shell, and whose support is moment free. By adding to these boundary conditions one that assumes that the resultant shear which each edge stiffener applies is the same in both the buckled and unbuckled state, the problem is shown to be the same as for a flat rectangular plate.

Buckling curves are given only for a square plate because of the numerous calculations required. These curves are similar to other buckling curves except that two systems are necessary according to an even or odd criterion for solution of the differential equation.
N. C. Costakos, USA

3575. Lotkin, O. I., Stability of rectangular cross-section thin-walled shells (in Russian). *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 101–108, 1954.

The loss of stability is characterized by the deflection of the shell in two planes, the slope at the cross sections of the shell, and the deformation of its cross-section contour. The plates forming the cross section are of different thickness. Integration of the differential stability equations is applied in the following three cases: (a) pure bending, (b) eccentric compression, (c) bending with uniformly distributed load and simultaneous eccentric compression. W. Wierzbicki, Poland

3576. Chilver, A. H., End-fitting effects in strut tests, *J. roy. aero. Soc.* **60,** 544, 275–277 (Technical Notes), Apr. 1956.

Based on the tangent-modulus approach and applying the Karman–Biot solution to buckling beyond the elastic range, author ob-

tains approximate solution for buckling load of pin-ended straight column with rigid end connections. Even under extreme practical conditions the effect of rigid end fittings is found to increase buckling stress by only about 5% above Euler stress.

G. G. Meyerhof, Canada

Structures

(See also Revs. 3515, 3531, 3542, 3547, 3548, 3549, 3550, 3551, 3553, 3602, 3626, 3647, 3693, 3764)

Book-3577. Guldan, R., The Cross method and its practical application [Die Cross-Methode und ihre praktische Anwendung], Wien, Springer-Verlag, 1955, xix + 472 pp. $17.15.

This is an excellent book on the moment distribution method. Presentation is very clear; paper and print are excellent. The author is well known from his book on "Frames and continuous beams" [in German, Springer-Verlag] which has already appeared in five editions.

Book consists of three parts. Part I includes everything which is necessary for the understanding and successful application of the moment-distribution method. This part starts with a chapter on the basic relationships of the theory of structures as they refer to the method in question. The difference between frames with lateral restraint and those without lateral restraint is clearly explained. The second chapter gives the theory and applications of the moment-distribution method for frames with members of constant cross section. The third chapter considers frames with members of variable cross section. Influence lines are discussed in the fourth chapter. The fifth, and final, chapter gives the influence of temperature.

Part II consists of 34 completely solved examples, Part III contains a collection of tables and graphs.

A. Phillips, USA

3578. Kron, G., Solution of complex nonlinear plastic structures by the method of tearing, *J. aero. Sci.* **23,** 6, 557-562, June 1956.

The tensor method developed by Kron for electric systems and applied by him and others for elastic structures is worked out for plastic structures. A brief but clear introduction to the tensor method for structures is given, showing how equations for structures are obtained by combining simple matrixes for the elements and for the topology of the structure. Structures may be subdivided into substructures, the solutions of which are combined. using matrix operations, to establish the equations for the complete structure.

Paper is an application to structures, the elements of which are plastic, satisfying the formulas by Wilder and Hoff. An illustrative numerical example is worked out.

B. Langefors, Sweden

3579. Bolcskei, E., Limit design of compressed bars, *Acta Techn. Hung. Budapest* **14,** 3/4, 377-400, 1956.

This study refers to the eccentrical compressed bar and supposes that the material of the bar is elastoplastic with given strain limit. The limit load of this bar is defined as that value of the loading force for which the limit strain will be attained at a point of the extreme fiber. The aim of the study is to demonstrate that the limit load so defined is not unique, because it depends on the "loading path," which is a curve in the coordinate plain P,e and characterizes the increase of P and e from zero to their final values. Here P is the value of the loading force, e is its eccentricity. The author believes that the divergences between the results of the different theories (Euler, Engesser, Kármán, Shanley, Müllersdorf-Csonka) are due to the fact that these theories followed different "loading paths." J. Barta, Hungary

3580. Pucher, A., Bending moments in edge beams of two-way ribbed road slabs (in German), *Bautech.-Arch.* no. 10, 3-20, 1955.

Author shows how the bending moments in the longitudinal beams can be calculated from the load on the plate, using two-dimensional plate theory. The influence fields for a few simple cases are given: the bending moment in the midsection of the beam for a plate with a particular dimension which is simply supported on either infinitely stiff or elastic beams. The extension to built-in edges is indicated. M. Botman, Holland

3581. Nowiński, J., Thin-walled doubly curved structural elements with high taper (in Polish), *Arch. Mech. stos.* **7,** 4, 533-560, 1955.

The theory developed is based on the assumption that the cross sections are rigid in their planes, and that the axis of the beam is perpendicular to a plane of fixture; the middle surface of the skin presents a surface of revolution.

The skin is assumed to be very thin, which permits neglect of its flexural and torsional rigidities and the assumption of a membrane state of stress not exceeding values which would cause buckling or yielding of the shell.

Considering the rotation of the cross sections about x-, y-, and z-axis, and taking into account translations and warping of the cross sections, deformations of the beam are determined. After determining the shearing strain and the unit elongations in the circumferential and meridional direction, stresses are found on the assumption that the material of the shell is curvilinearly orthotropic. Subsequently, the differential and integral equations of equilibrium are derived, and self-equilibrating stress systems are used.

After examining torsion and bending of the beam, author investigates an example of a spherical shell loaded with concentrated force at the top.

Comparison with prior investigations shows that the consideration of the double curvature of the shell and of its high taper presents a generalization of the well-known theory of thin-walled conical beams with small taper. J. Rutecki, Poland

3582. Michalos, J., Direct design of hingeless arches of constant section, *Civ. Engng., N. Y.* **26,** 7, 61-64, July 1956.

Paper gives diagrams for the influence values of the spring moments and reactions on circular, parabolic, and semi-elliptic arches. C. J. Bernhardt, Norway

3583. Vainberg, D. V., Stress concentration around a gallery in a dam (in Russian), *Gidrotekh. Stroit.* **22,** 9, 7-10, Sept. 1953.

An approximate computation of these stresses is given for:

(a) Loading by the dam weight. An approximate method is used, in which radial stresses on the walls of the hole are computed as if the hole did not exist. These stresses are introduced in an opposite sense as an external loading on the walls around the hole, cut in an elastic infinite body. The stresses in the tangential direction on the walls around the hole are given by summarizing the stresses computed for both cases.

(b) Loading by water pressure. It is shown that the intensity of the stresses around the place of the hole is the most important factor and that the exact distribution of these stresses is only of minor importance. Therefore, the stresses in the center of the holes are computed first as if the hole did not exist. Then a homogeneous field of these stresses is investigated and the stresses around the hole are computed. For various shapes of the hole the formulas given by G. N. Savin (1951) are used.

The results of the method are demonstrated by an example and the distribution of the stresses around the hole is charted. Author states that his results agree with the results of photoelasticity measurements. V. Mencl, Czechoslovakia

3584. Rowe, P. W., Present situation on retaining wall design, *Struct. Engr.* **34,** 6, 204-217, June 1956.

3585. **Koenigsberger, F., and Mohsin, M. E., Design and load carrying capacity of welded battened struts,** *Struct. Engr.* **34,** 6, 183-203, June 1956.

3586. **Chatterjee, B. K. and Bobrowski, J., Friction losses in prestressing under site conditions,** *Civ. Engng., Lond.* **51,** 601, 765-767, July 1956.

3587. **Tremmel, E., and Wogrin, A., Mathematical-statistical evaluation of materials and reports on concrete** (in German), *Bauingenieur* **30,** 1, 28-32, Jan. 1955.

3588. **Gedizli, H. S., and Fuchssteiner, W., On the subject of self-supporting spiral stairs** (in German), *Beton u. Stahlbeton.* **50,** 9, p. 247, Sept. 1955.

A useful table for practicing engineers, discussed in a previous paper [AMR **8,** Rev. 2705], is given.

From authors' summary

3589. **Granholm, J. W., The use of closed-curve equations of variable degree in airplane fuselage lofting,** *Aero. Engng. Rev.* **13,** 7, 52-57, July 1954.

The history of lofting practice is reviewed. Requirements for various airplane fuselage types are noted briefly. Some lofting methods now in use are described. The use in lofting of closed curve, variable-degree equations is suggested. A typical family of fuselages is set up using such equations, and the lofting of one such fuselage using an electronic digital calculator is described. The extension of such procedures to hull lofting is briefly indicated. From author's summary

Rheology

(See also Revs. 3539, 3540, 3578, 3696)

3590. **Trifan, D., Stress theory of plastic flow,** *J. Math. Phys.* 35, 1, 44-52, Apr. 1956.

The typical stress-strain law for a work-hardening plastic material gives the strain increment as a function of the instantaneous stress and the increment of stress. In contrast to this "strain theory" of plastic flow, author considers a "stress theory" that lets the stress increment depend on the instantaneous strain and the strain increment. Typical stress-strain laws of this type are discussed, and two absolute minimum principles associated with this theory of plasticity are established.

Courtesy of Mathematical Reviews W. Prager, USA

3591. **Thomas, T. Y., Characteristic surfaces in the Prandtl-Reuss plasticity theory,** *J. rational Mech. Analysis* **5,** 2, 251-262, 1956.

Author discusses the problem of characteristic surfaces in the Prandtl-Reuss theory of plasticity. For the surfaces discussed a differential equation is developed.

The problem of characteristic surfaces is developed through the general dynamical relations, equations of continuity and motion, and three special relations. These special relations comprise one of incompressibility, one for the yield condition, and the generalized Prandtl-Reuss relation employing the absolute time derivative of the components of the stress deviation.

The coordinate system for a moving surface (x system) is chosen as a rectangular one. To satisfy the condition of a characteristic surface in any one region, transformation is considered into a second rectangular surface (y system) leaving invariant all equations of the x-system.

The differential equations relative to the second specially selected coordinate system (y system) lead to a determinantal condition. The characteristic condition is deduced from the determinant. The invariant formulation of the characteristic condition is discussed.

Author shows that characteristic surfaces can be identified with wave or singular surfaces of order one relative to the flow quantities. F. Garofalo, USA

3592. **Hodge, P. G., Jr., and Romano, F., Deformations of an elastic-plastic cylindrical shell with linear strain hardening,** *J. Mech. Phys. Solids* **4,** 3, 145-161, May 1956.

The particular short shell considered is subjected to uniform external pressure and relatively small outwardly directed ring forces at both ends. Isotropic strain hardening is assumed and the circumferential force-axial bending-moment yield curve is approximated by a circumscribed rectangle. As a consequence, the plastic curvature is zero for the range of problems analyzed. The conclusion is reached that "as long as any part of the shell is elastic, the neglect of even a substantial amount of strain hardening will yield a reasonably accurate solution. On the other hand, for value of P such that the shell is fully plastic, the elastic strains do not contribute significantly and rigid strain-hardening theory can be used."

Reviewer commends the very appreciable extension of his work to strain hardening but cautions against complete acceptance of numerical results. Replacement of the actual yield and subsequent loading curves by a rectangle has been shown to be fairly satisfactory for limit load calculations and is probably good for average deflection. It is not as good for details of stress distribution. Also, when the hoop stress is compressive, buckling is likely early in the plastic range. D. C. Drucker, USA

3593. **Olszak, W., The plane problem of the theory of plastic flow of nonhomogeneous bodies,** *Bull. Acad. Polonaise Sci.* (IV) **3,** 3, 119-124, 1955.

Author considers general plane problem and then particularizes discussion to a thick-walled nonhomogeneous cylinder. It is pointed out that effect of taking nonhomogeneity into account will lead to considerable savings in weight as compared to the equivalent homogeneous cylinder. H. H. Hilton, USA

3594. **Jordan, T. F., and Thomsen, E. G., Comparison of an unsymmetric slip-line solution in extrusion with experiment,** *J. Mech. Phys. Solids.* **4,** 3, 184-190, May 1956.

Similarity between axisymmetric tube extrusion and analogous plane strain case is established experimentally. Extrusions were carried out using pure lead. Maximum shear-stress directions and velocities obtained by the analysis of the deformation of a square grid scribed on a central plane are compared with theory. Maximum shear-stress directions agree closely, but extent of deformation zones differs due, authors suggest, to neglect of elastic strains.

Velocity vectors show only qualitative agreement.

The theory underlying an interesting mechanical device for drawing slip-line fields is outlined and brief details of the construction of the instrument are given. F. Ellis, England

3595. **Johnson, W., Extrusion through square dies of large reduction,** *J. Mech. Phys. Solids* **4,** 3, 191-198, May 1956.

Making the assumption that dead metal zones can exist in corner between die and container for extrusion through square dies, author proposes slip-line fields for four cases. Smooth die face, smooth container wall; smooth die, rough container; rough die, smooth container; rough die, rough container.

Velocity conditions are said to be satisfied. Calculations of extrusion pressure for reductions up to 0.97 are made for the four cases. F. Ellis, England

3596. Pope, J. A., and Andrew, J. E., The effect of torsional overstrain upon the static strength of spring steel, *Proc. Instn. mech. Engrs.* **169,** 19, 345-360, 1955.

Paper describes the effect of torsional overstrain and subsequent tempering on the elastoplastic properties of spring steel. It is shown that, after the tempering heat treatment, the length of the elastic portion, which is the sum of the elastic strengths in the positive and negative direction, is unaffected by the degree of overstrain and equal to that of the original metal. It follows from this that the strength in the direction of twisting is increased and the strength in the opposite direction is decreased. This is commonly known as the Bauschinger effect.

A practical conclusion to be drawn from this paper is that, if a spring is to be used about a zero mean stress, no prestrain should be effected. However, if the spring is to be stressed such that the mean stress is displaced from zero, the spring should be prestrained in the same direction. In addition, the springs should always be tempered after prestraining.

A. D. Schwope, USA

3597. Maringer, R. E., Marsh, L. L., and Manning, G. K., Investigation of plastic behavior of binary aluminum alloys by internal-friction methods, *NACA TN* 3681, 44 pp., June 1956.

Paper contains a large amount of test data on internal friction in alloys of aluminum containing small (1 to 5%) amounts of either copper or magnesium. Such effects as the alloy content, the amount of aging, and the presence of plastic deformation were investigated. The manner in which the shear modulus varied with changes in internal friction was also studied. The behavior is analyzed in terms of dislocation theory.

E. A. Davis, USA

3598. Kasimov, A. F., and Mirzadzhanzade, A. Kh., Various forms of equations for viscoplastic flow and the law of hydrodynamic similitude (in Russian), *Prikl. Mat. Mekh.* **19,** 3, 348-352, 1955.

Author derives fundamental differential equations of flow which he considers to be necessary for determining the hydraulic losses of viscoplastic flow of liquids, such as clay solution, cement solution, etc. He assumes that the viscoplastic flow is subject to Shvedov-Bingham law and obtains formula for modulus of plasticity. The components of stressed state are substituted in Cauchy equations. It is assumed that the viscoplastic liquid is incompressible. The equations are transformed into vector-tensor form and Lamb's form is used. Author generalizes the Helmholtz equations for study of turbulant flow for viscoplastic liquids. He uses dimensionless parameters which can be derived from the basic differential equations for the viscoplastic flow. These dimensionless numbers are known under names of Froude, Ilyushin, Euler, Strouhal, Reynolds, Lagrange, Stokes. The last three of these parameters exist in two forms, one for the viscoplastic, and another for plastic, liquids. The Ilyushin number is a parameter which pertains to the identification—whether the flow of a given liquid is viscoplastic or plastic. Formulas for these parameters contain change in pressure rather than absolute values.

For certain stabilized flows author observes that: (1) Inertia forces and gravity forces have a small effect when compared with the viscous forces of the limiting shear and the pressure; (2) viscous forces of the limiting shear and gravity forces have a small effect when compared with pressure and inertia forces; (3) inertia forces and pressures are of secondary importance when compared with the viscous forces of the limiting shearing stress and the gravity forces; (4) viscous forces of the limit shearing stress and the pressures are negligible when compared with inertia forces and gravity forces.

Author gives examples and describes conditions for the parameters and the functional relationships among these numbers. For example, a functional relationship between Euler and Reynolds numbers is used for the general case of flow in round tubes. One of the coefficients in authors' formula for change in pressure is a function of Reynolds number. Buckingham's formula was used in determining this coefficient. For viscous flow, authors' formula becomes the D'Arcy-Weissbach formula and the expression for the above coefficient becomes the usual Stokes formula.

V. A. Valey, USA

3599. Schwarzl, F., and Staverman, A. J., Higher approximation methods for the relaxation spectrum from static and dynamic measurements of visco-elastic materials, *Appl. Sci. Res.* (A) **4,** 2, 127-141, 1953.

Failure, Mechanics of Solid State

(See also Revs. 3597, 3624, 3625, 3785)

3600. Freudenthal, A. M., and Gumbel, E. J., Physical statistical aspects of fatigue, pp. 117–158, Advances in Applied Mechanics. Vol. IV (Dryden, H. L., von Karman, T., and Kuerti, G., editors), New York, Academic Press, Inc., 1956.

Basic concepts of the progressive damage in crystalline metals are reviewed from the viewpoint of the micromechanisms leading to fracture and the statistical nature of the phenomena. The inconclusiveness of current fatigue theories is emphasized; the mechanism of intensified slip in localized striations accompanied by local severe increases of temperature is apparently valid but difficult to express quantitatively. The statistical theory of extreme values is developed in detail and advocated by the authors for estimation of the probability of surviving a given fatigue life N cycles of a given stress amplitude S, or for expressing the distribution of N for samples tested at constant amplitude S. A shortened fatigue testing procedure, cumulative damage, and the distribution of fatigue strength for constant fife N are interpreted in terms of extreme-value theory.

Reviewer's comment: There still exists doubt as to whether any one of the mathematical distribution functions can adequately fit experimental fatigue data well enough to permit extrapolation to low probabilities of failure (for which they are proposed in practical use).

T. J. Dolan, USA

3601. Bore, C. L., The presentation of fatigue data for fatigue life calculations, *J. roy. aero. Soc.* **60,** 545, 331–346, May 1956.

A simple endurance chart for the presentation of basic fatigue data is described. Chart shows effect of mean stress, residual stress, and pretension, and is easily constructed from fatigue test results. Charts enable relative fatigue strengths and structural efficiencies of different materials to be compared.

From author's summary by W. J. Anderson, USA

3602. Heywood, R. B., The influence of pre-loading on the fatigue life of aircraft components and structures, *Aero. Res. Counc. Lond. curr. Pap.* 232, 20 pp. + 8 figs., 1956.

Tests on aircraft components and structures are described which show that preloading can have a marked influence on fatigue behavior. Tensile preloading may increase the life—in one instance a hundredfold improvement was obtained—and compressive preloading may reduce the life. The effect is attributed to residual stresses and to load redistributions induced by preloading.

From author's summary

3603. Fisher, W. A. P., and Yeomans, H., Investigation of the fatigue of extruded tubular booms, *Aero. Res. Counc. Lond. curr. Pap.* 234, 6 pp. + 5 tables + 7 figs., 1956.

Earlier tests on Viking tubular spar booms having shown considerable scatter and low fatigue strength, a special program of tests was undertaken in order to ascertain the cause.

Three types of specimen made from aluminum-alloy extruded tube to Material specification D.T.D. 364 were tested and the results compared. The types of specimen were:

(a) Extruded tube specimens lightly machined on the outside, having transverse holes drilled through the tube. (These represented the critical section of the Viking replacement and Valetta spar boom).

(b) Plain extruded tube with the center portion reduced to insure failure in the test section.

(c) Solid polished bar specimens made from the walls of the extruded tubes.

The results showed that the fatigue strength of the plain tube, with the original extruded bore, was less than half that of the polished bar. Fatigue cracking started in every tube from an obvious flaw on the inner surface. From authors' summary

3604. Hyler, W. S., Abraham, E. D., and Grover, H. J., Fatigue crack propagation in severely notched bars, *NACA TN* 3685, 15 pp. + 4 tables + 11 figs., June 1956.

Fatigue tests were made in rotating bending on severely notched bars machined from 2024-T4 aluminum-alloy extruded round rods. Two sizes of specimens were studied, ¼-in.-diam. and 2-in.-diam. specimens. The smaller specimens were notched with a V-groove and had notch severities K_t of 5.2. The larger specimens also contained V-grooves with notch severities K_t = 5.2 and 13.9.

It was found that, unlike behavior sometimes observed for unnotched and mildly notched bars, fatigue cracks initiated early in the lifetime of the severely notched specimens. In the case of the ¼-in.-diam. bars, initiation occurred (at a test stress of 22.5 ksi) in less than 0.25% of the average lifetime of the specimen.

It appeared that cracks in large-diameter specimens had a period of rapid crack growth followed by a marked tapering off in rate of crack propagation. This behavior may have been associated with compressive residual stresses, which were demonstrated qualitatively to be present. Other factors also may have influenced this behavior. From authors' summary

3605. Nielsen, J., Theory of cohesive failure of concrete (in Danish), *Bygnsstat. Medd.* **26**, 1, 33–50, Aug. 1955.

3606. Lape, E. M., and Lubahn, J. D., On the relations between various laboratory fracture tests, *Trans. ASME* **78**, 4, 823–835, May 1956.

Rational design against fracturing of notch-brittle metal members and structures depends upon establishing relationships between laboratory experiments and service performance. Results from tension tests, bend tests, and disk-bursting tests, each involving notched and unnotched specimens, and Charpy impact tests for an alloy steel heat-treated to several strength levels, were analyzed. Although correlation was found in several instances, this paper emphasizes the important areas where the relationship between these experimental results is not understood. Several tentative generalizations and approaches, both analytical and experimental, are suggested to achieve better correlation, first between various laboratory tests and eventually with service performance.

H. T. Corten, USA

3607. Murphy, W. J., and Stout, R. D., Fracture behavior in the notch slow-bend test, *Welding J.* **35**, 4, 169-s–180-s, Apr. 1956.

Studies were made of Kinzel-type specimens cut from A-302, A-7, and A-201 steel plates to study the effect of weld metal and heat-affected zone in initiation and propagation of brittle failure. Two factors that influenced the transition temperature were: (a) The tendency of the weld zone to initiate cleavage failure, and (b) the ability of the base metal to prevent propagation of cleavage failure. Authors conclude that welding decreased the notch toughness by providing a zone to initiate cleavage more readily than the base metal. Postheating may improve the notch toughness of welded specimens by altering the structure responsible for cleavage initiation. A fine tough structure capable of interrupting a cleavage crack may also influence the welded transition temperature. T. J. Dolan, USA

3608. Bowie, O. L., Analysis of an infinite plate containing radial cracks originating at the boundary of an internal circular hole, *J. Math. Phys.* **35**, 1, 60–71, Apr. 1956.

The plate is assumed to sufter (1) uniform ("all around") tension, (2) simple uniaxial tension. Using Griffith's theory [*Phil. Trans. roy. Soc. Lond*, (A) **221**, p. 163, 1921] author calculates critical tension at which radial cracks equal and finite in length arranged at equal distances around the circular hole start to spread. Expression for elastic strain energy, required by this theory, is found by complex variable method of Muskhelishvili [*Math. Ann.* **107**, 282–312, 1932–33]. Numerical results are given for both load systems for the cases of one and two cracks. These results can be used after slight modification for the plane strain problem of a hollow cylinder of very large wall thickness with longitudinal cracks originating along the inside surface, under internal pressure. A. Werfel, Israel

3609. Chechulin, B. B., Metal brittleness and the size effect (in Russian), *Zh. tekh. Fiz.* **25**, 1, 125–134, Jan. 1955.

An equation relating the critical temperature of brittleness (the temperature at which crystalline portions appear in the fracture) to the size of similar notched specimens has been set forth and has the form $1/T_{cr} = K \lg M + B$, where M is the common dimension of the sample, K and B constants of the material. The theoretical reasoning for this equation is based on the generalized scheme of A. F. Joffe and the statistical nature of brittle fracture. A new characteristic reflecting the tendency of a steel to the size effect is proposed; this characteristic is called the size coefficient of the critical temperature of brittleness. It is shown that the physical-metallurgical-type brittleness (temper brittleness and bainitic brittleness), the individual peculiarities of the melt, and the quality of the steel are reflected but little in the magnitude of the size coefficient, although the influence of the quality and the melt require further verification. The temperature of the temper after the quench apparently had a significant effect on the size coefficient. It was established that the higher the tempering temperature the greater the absolute magnitude of the size coefficient of brittle temperature.

From author's summary by A. M. Turkalo, USA

3610. Gotzlinger, O. J., Brittleness data and brittle fracture (in Swedish), *Tekn. Tidskr.* **86**, 15, 335–339, Apr. 1956.

3611. Frohmberg, R. P., Barnett, W. J., and Troiano, A. R., Delayed failure and hydrogen embrittlement in steel, *Trans. Amer. Soc. Metals* **47**, 892–925, 1955.

Further experimental work has been carried out concerning hydrogen embrittlement in steel, in this case with special connection with the phenomenon of delayed fracture that becomes more and more important in modern technics with the use of high-strength materials. Authors refer to three possible mechanisms, *i.e.*, of Zapffe (planar pressure theory), Brown and Baldwin (Cottrell atmospheres surrounding dislocations), and Orowan (Griffith's crack theory for glass). They conclude from their very extensive experiments that each one might be capable of explaining the results, although the Griffith concept is judged attractive in particular. The research demonstrates the effects of strength level of the material, the notch acuity of the test bar, the aging time at room temperature, and the importance of the distribution of the hydrogen. G. de Witte, Holland

3612. Roop, W. P., Cold brittleness in notched wide plates of ship steel, *David W. Taylor Mod. Basin Rep.* 853, xiii + 153 pp., May 1954.

Author analyzes all available data on notched wide-plate specimens by an iterative procedure. Calculating the energy densities in the characteristic zones of deformation near the notch, he attributes the width effect to the interaction between the strain field during plastic flow and that associated with incipient fracture.

J. A. Haringx, Netherlands

3613. Isaksson, A., Ratobnov's theory of creep (in Swedish), *Inst. Hållfasthetslära, KTH, Stockholm, Publ.* 110, 24 pp., 1955.

Fundamentals of Rabotnov's theory of creep are recapitulated after the American translation [*NACA TM* 1353, 1953] of the orginal Russian paper, and some additions are made. In this creep theory, two phenomena, deformation hardening and reverse creep, are considered. These factors have not been treated in earlier theories of creep. Rabotnov applies the phenomena using Volterra's heredity integral, through which not only the actual value of the stress but also the loading history is considered in his creep mechanics. A fictitious stress φ is defined, and it is stated that a creep problem can be solved if the movement of the point with the actual values of φ and the strain ε as coordinates is followed in a φ-ε-diagram. If the process is active, i.e., the strain energy is increasing, this point will follow the usual static stress-strain curve; if the process is not active, it will follow a line parallel to $\varphi = E \cdot \varepsilon$. It is also shown that creep and relaxation obey different laws. The theory is applied to reverse creep and a formula is derived which indicates a linear relation between the stress and the reverse strain. Pure bending is then studied, and it is shown that at a given point the stress will be proportional to the applied couples whether these are time constant or not. Thus there is no re-arrangement of the stresses during the creep process. When the theory is applied to a three-dimensional case, a circular tube subjected to internal pressure, it is also shown that no re-arrangement of stresses will occur.

In the criticism of the theory it is stated that the application of the theory to repeated loading must be made with some care. When generalizing to three-dimensional loading Rabotnoz is supposing that the elastic volume change can be omitted. This is only correct when the deformations are small. Obviously, Rabotnov's theory must, therefore, be used with the greatest care when the stress is two- or three-dimensional. B. Löfblad, Sweden

3614. Oding, I. A., Present-day concepts of the mechanism of plastic deformation and failure in the creep of metals (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 8, 110–118, Aug. 1954.

3615. Fisher, J. C., Application of Cottrell's theory of yielding to delayed yield in steel, *Trans. Amer. Soc. Metals* **47**, 451–462, 1955.

According to Cottrell, dislocations in iron are pinned up by absorbed carbon, nitrogen, and other solute atoms. Yielding occurs when dislocations are freed from their adsorbed solute atoms with the aid of thermal energy fluctuations. Based upon this model, the temperature and stress dependence of the delay time for the yielding of steel is calculated and is compared with experiment. The temperature dependence of the yield stress also is calculated, and found to be of the form (*stress*) × (*temperature*) = *constant*, in good agreement with experiment over a wide temperature range. From author's summary by G. de Witte, Holland

3616. Henke, R. W., Resistance of materials to mechanical corrosion, *Prod. Engng.* **27**, 1, 194–197, Jan. 1956.

A brief review of the causes of stress corrosion, corrosion fatigue, impingement, erosion, and fretting, followed by guides to the choice of the most resistant materials, and remedies possible in design. From author's summary

3617. Godfrey, D., and Bailey, J. M., Coefficient of friction and damage to contact area during the early stages of fretting I. Glass, copper, or steel against copper, *NACA TN* 3011, 23 pp., Sept. 1953.

Experiments were conducted to measure the coefficient of friction μ and to determine the damage to the contact area during early stages of fretting of copper at a frequency of 5 cpm. Specimen combinations of copper against glass, copper against copper, and copper against steel, as well as various copper oxide films and powder compacts, were used.

The results lead to the conclusion that fretting of copper starts with the same mechanical damage that occurs during unidirectional sliding. Fretting of copper against glass, copper against copper, and copper against steel starts with adhesion and metal transfer (galling) with accompanying high μ values (< 1.0) the same as those obtained during unidirectional sliding. After the initial high values of μ, a reduction in μ was observed, associated with reduced plowing and an increasing concentration of debris in and around the contact area. After approximately 100 cycles of fretting, μ reached a constant value (0.5–0.6), approximately the same as that obtained with compacts of either cuprous or cupric oxide.

The presence of preformed cuprous or cupric oxide films on copper does not delay the occurrence of fretting but only lowers the initial coefficient of friction.

From authors' summary

3618. Hundy, B. B., The strain-age hardening of mild steel, *Metallurgia, Manchr.* **53**, 319, 203–211, May 1956.

The effects of strain ageing on the mechanical properties of mild steel are reviewed, and a modification of the dislocation theory of strain ageing to cover the change in strength and ductility during ageing is discussed. A reduction in the nitrogen content (to below 0.002% say) would improve mild steel from the point of view of ductility, but it would still be subject to a pronounced return of the yield point on ageing.

From author's summary

3619. Kennedy, A. J., A reconciliation of certain recovery properties in metals, *J. Mech. Phys. Solids* **4**, 3, 162–166, May 1956.

A variety of time and temperature functions have been proposed to express the mechanical and electrical properties of metals. It is demonstrated that these can be reconciled with the behavior of a particular kind of physical model built up from relaxation-type elements. From author's summary

Material Test Techniques

(See Rev. 3606)

Mechanical Properties of Specific Materials

(See also Revs. 3546, 3597, 3605, 3607, 3609, 3611, 3618, 3760, 3764, 3785)

3620. Nichols, R. W., The mechanical properties of carbon steel wire at low temperatures, *J. Iron Steel Inst. Lond.* **182**, part 4, 337–347, Apr. 1956.

Tensile, impact, fatigue, and reverse bend tests were made at temperatures ranging from + 20 to – 60 C on 0.044-in. diam. carbon-steel wire similar to that used in wire-rope manufacture. The materials were 0.5% and 0.75% C contents and each was tested in the annealed, as-drawn, and electrogalvanized condition.

The proof stress and U.T.S. values in the tensile tests were found to increase with decrease of temperature, while the tensile reduction in area and notch-bend impact-energy values decreased:

these effects were relatively small at temperatures down to −60 C. In the fatigue tests, the endurance limit increased with decrease of temperature except for the electrogalvanized materials, which showed decreases in endurance limit associated with crack formation in the zinc coating.

Endurance tests at applied strains of up to 5% were carried out by reverse-bending around formers. At each temperature, the rate of decrease of endurance with increase of applied strain became markedly greater when the deformation became predominately plastic. Within this higher strain range, decrease of temperature produced a deterioration in specimen life at a given strain level for all the materials. The reverse-bend properties for the electrogalvanized wires were superior to those for the as-drawn at + 20 C, but showed a greater deterioration on cooling to −60 C, especially when the results were compared on an equivalent stress basis. From author's summary

3621. **Nichols, R. W., The hardness of some carbon and low-alloy steels at low temperatures,** *J. Iron Steel Inst. Lond.* **182,** part 4, 348–354, Apr. 1956.

In order to determine the effects of low temperature on various proposed relationships between hardness and tensile properties, tests were made at +18, −70, and −196 C. The D.P.H. number was approximately proportional to the tensile stress at 8% strain throughout these tests, whereas the U.T.S./D.P.N. ratios for several of the steels were smaller at −196 C than at the higher test temperatures. This was partly due to reduced initial rates of strain-hardening in these steels at −196 C, which were also revealed in lower Meyer indexes obtained from ball hardness tests at this temperature. At all temperatures, stress/strain curves calculated from the ball hardness results showed good agreement over the range 4–8% strain with comparable curves obtained directly in tension tests. From author's summary

3622. **Murray, J. D., Measurement of stress-relieving temperatures of some power plant steels,** *Metal Treatm.* **23,** 127, 131–134, Apr. 1956.

The author describes a laboratory method for determining the stress-relieving temperature of a steel, giving examples of results on some low-alloy molybdenum and chromium-molybdenum steels, and a high-alloy steel. From author's summary

3623. **Sims, R. B., Yield-stress/strain curves and values of mean yield stress of some commonly rolled materials,** *J. Iron Steel Inst. Lond.* **177,** part 4, 393–399, Aug. 1954.

The yield stress in plane compression has been measured for a number of commonly rolled materials, and the results are presented, together with values of the mean yield stress, in the hope that they will be of value for calculating roll loads and power in production rolling mills.

The experimental method is described briefly. An indication is given of its accuracy by a comparison with the tensile test and, for a few materials, between measured rolling loads and corresponding values calculated from the mean yield stresses.

From author's summary

3624. **Hennephof, J., The tearing of aluminium foils,** *J. Mech. Phys. Solids* **4,** 3, 172–183, May 1956.

To investigate the tearing of foils, thin hard aluminum foils (thickness 0·0188 cm) were provided with two parallel cuts. The part of the foil between these two cuts was torn out while the rest was clamped against a flat surface. The base angle of the triangular part that is torn out was measured, and also the tearing-force. The angle under which the tearing takes place was variable and appeared to be of great importance.

The energy for tearing a unit length out of the foil is the essential quantity (and not the tearing force). This energy is made up of two parts: the energy for bending the foil and the energy for the plastic deformation of the borders of the tear. The first quantity was determined separately; it was also calculated in good agreement with the measurements; it proved to be the greater part of the total tearing energy. The energy necessary for forming the fresh surfaces is thought to be negligible.

From author's summary

3625. **Hartman, A., Influence of elevated temperatures up to about 450 °C on the mechanical properties of the aluminium alloys, titanium and titanium alloys,** *Nat. LuchtLab. Amsterdam Rap.* M. 1987, 49 pp. + 62 figs., 1955.

Paper gives the results of a search of the literature on the influence of elevated temperatures up to about 450 C on the mechanical properties of the aluminum alloys (the most important structural materials for aircraft of the present), the stainless steels, and titanium and titanium alloys, their possible successors when higher mechanical properties at elevated temperatures will be required. From author's summary

3626. **Cadambe, V., Srivastava, K. C., Titanium—a prospective metal for aircraft,** *Defence Sci. J.* pp. 17–26, Oct. 1954.

Plasticity, Forming and Cutting

(See also Revs. 3493, 3594, 3595, 3603)

3627. **Christopherson, D. G., and Naylor, H., Promotion of fluid lubrication in wire drawing,** *Instn. mech. Engrs. Proc.* **169,** 35, 643–653, 1955.

A factor limiting the rate at which wire can be drawn through a die is the severe die wear which may occur at high speed. If hydrodynamic lubrication could be induced, wear would probably be much reduced. It is suggested that this can be done by supplying oil to the die entry at a pressure comparable with the wire yield stress. The necessary pressure can be conveniently generated by causing the wire to approach the die through a tube of slightly larger diameter than the wire, sealed on to the inlet side of the die.

Experiments showed that the die friction is thereby so reduced that, even allowing for the drag in the tube, the total drawing force is less than with existing methods of soap lubrication; and tests with steel dies have shown large reductions in wear. A theory of the behavior of the wire in the inlet tube and of the temperature distribution in the system is included. The former is based on the hypothesis that the wire follows that path in the tube which leads to minimum power dissipation, assuming laminar viscous flow; the experimental results are consistent with it.

Reviewer believes that this is a most important investigation, both from a practical viewpoint and as an interesting new application of the variational principle to viscous flow.

G. D. S. MacLellan, England

3628. **Wistreich, J. G., Investigation of the mechanics of wire drawing,** *Instn. mech. Engrs. Proc.* **169,** 35, 654–687, 1955.

Round wire was drawn slowly and without backpull through dies with bores in the shape of truncated cones, in a study of the relations between external forces and process parameters. The drawing force, the mean die pressure, and the mean coefficient of friction were measured (using a split die technique). The investigation has revealed weaknesses in all wire-drawing theories; the use of Hill and Tupper's sheet-drawing theory [AMR **1,** Rev. 1647] for the prediction of forces in wire-drawing is not justified.

Semiempirical formulas for the forces have been derived. A simple relation between tool-stock configuration and nonhomogeneity of deformation was discovered, also applicable to the mechanics of swaging. The assumption that the deformation is independent of the wire properties is not valid for annealed wires drawn with very light reductions, but is acceptable otherwise. The occurrence of thickening of the wire before entering the die, and its continued thinning beyond, deserves attention in bar drawing. There was no correlation between die pressure and coefficient of friction.

From author's summary by G. D. S. MacLellan, England

3629. Tabor, D., Elastic work involved in rolling a sphere on another surface, *Brit. J. Appl. Phys.* **6,** 3, 79-81, Mar. 1955.

In a previous investigation on the mechanism of rolling friction in the elastic range, author had found the rolling resistance could be attributed only to a small degree to the differential slip between the rolling surfaces; the major part seemed to arise from elastic hysteresis. As calculations for cylindrical surfaces are not easy, spherical surfaces—for which the Herzian equations may be directly applied—are treated in this paper. The tangential forces are assumed small, so that stresses and strains are supposed the same as those arising in static loading. The results show that the work involved in rolling a sphere on a flat surface is substantially the same as that involved in rolling a sphere in a groove of almost the same curvature as the sphere. This conclusion agrees with the previous experiments made by author on spheres rolling on rubber surfaces. D. DeMeulemeester, Belgium

3630. Frenkel, M. S., Crushing and mixing under controlled conditions—a new principle theoretically developed, *Engineering* **182,** 4714, 41-42, July 1956.

3631. Rose, H. E., and Evans, D. E., The dynamics of the ball mill. Part I. Power requirements based on the ball and shell system. Part II. The influence of the powder charge on power requirements, Instn. mech. Engrs. Prep. 22 pp., 1956.

Hydraulics; Cavitation; Transport

(See also Revs. 3665, 3688, 3738, 3748)

Book—3632. Chebotarev, A. I., Continental hydrology, [Gidrologiia Sushi], Leningrad, Gidrometeorizdat, 1955, 398 pp. $2.

This is a new standard textbook on hydrology for use in technical schools; book is also of value for practice of hydraulic engineering. Contents: Water circuit, regime of underground water, lakes, swamps, glaciers, rivers and their valleys; Computation of river runoff, direct and approximate methods; Probability of average, maximum, and minimum discharges; Silt runoff computations. S. Kolupaila, USA

Book—3633. Troskolański, A. T., Applied hydromechanics [Hydromechanika techniczna], Vol. I, Rational hydromechanics, Warsaw, Państwowe Wydawnictwa Techniczne, 1951, xx + 352 pp.

Author is known by his "Hydromechanics," 1925, and "Manual for water-meter testing," two vols., 1931, 1936. His new work is in three volumes. Volume 1 contains inspiring introduction, complete treatise on hydrostatics, a classical presentation of dynamics of ideal liquids, and a new approach to dynamics of real liquids. Turbulent flow is based on the rational theory by a Polish scientist M. Broszko (1880-1954), who had improved equations by Euler and Reynolds in order to obtain better agreement with experimental data. His work, developed since 1921, has been published in "Annales de L'Académie Polonaise des Sciences Techniques," 1946, in French. According to author, this work is a swing to further development of dynamics of real liquids.

Author may be commended for an excellent innovation: index of terms is given (on 40 pages) in five languages: Polish, Russian, English, French, and German. Using this valuable dictionary, everyone can understand Polish text! S. Kolupaila, USA

Book—3634. Troskolański, A. T., Applied hydromechanics [Hydromechanika techniczna], Vol. II, Hydraulics, Warsaw, Państwowe Wydawnictwa Techniczne, 1954, xii + 460 pp.

This second volume contains fundamental notions of dimensional analysis, theory of mechanical similarity, free motion of liquids (orifices, nozzles, weirs), flow in open channels and through pipes, water hammer, impact of water, theory of turbines and pumps, jets, automatic valves, theory of fluid friction, resistance of fluids, and underground water movements.

Many chapters in this volume are on the level of modern textbooks on fluid mechanics, although distribution of material is not usual. Several formulas for weirs are presented, but widely used formulas for open channels and for pipes are missing or mentioned by name only. Backwater computations are very clear; a method of a Polish scientist N. Haponowicz (1917) is presented, which is very little known. The more modern methods are not mentioned; author could recall that another Polish method by V. Czarnomski, 1914, is the same as the method by A. Husted, published in 1924. This volume also has an index in five languages: Polish, English, French, German, and Russian. S. Kolupaila, USA

3635. Datta, R. R., An approximate analytical solution of the standing wave equation, *J. Instn. Engrs., India* **36,** 8 (1), 1662-1667, Apr. 1956.

Paper deals with the uncommon problem of finding the sequent depths for an hydraulic jump in a rectangular channel when rate of discharge and energy loss in the jump are known. Momentum and energy equations for the jump are combined and depths are obtained from the resulting equation by successive approximation. Reviewer finds method quite laborious, with little or no advantages over a trial solution of the basic momentum and energy equations. W. DeLapp, USA

3636. Franke, P., Theoretical consideration of jet contraction in flows under a sluice gate (in German), *Bautechnik* **33,** 3, 73-77, Mar. 1956.

Author analyzes the contraction of an irrotational stream issuing from the opening of a sluice gate. In the first part of the analysis use is made of the results of von Mises (who did not consider gravity) for flow from a two-dimensional opening. Following Pajer, author first assumes the hodograph of the free surface to be a quarter of an ellipse, but later arbitrarily modifies it into a quarter-circle in order to use von Mises' results. The significance of any result obtained through such an arbitrary procedure is dubious. In the second half of the paper author tries to solve the problem by following A. Koch, whose original work suffered much from inexactness, with understandably poor results as compared with the experimental data given in the paper.

The only exact (in the sense that no assumption in addition to irrotationality is made) solution for the sluice-gate problem is that of Southwell and Vaisey [*Phil. Trans.* (A) **240,** 117-161]. This gives a contraction co-efficient of 0.63 for a ratio 0.577 of the height of the opening to the upstream depth, in better agreement with author's experimental curve than any of his curves obtained from calculation. This leads reviewer to believe that more work should be done on this important problem of hydraulics using Southwell's approach. C. S. Yih, USA

3637. Fazekas, K., Some new hydrometric instruments (in Hungarian), *Res. Inst. for Water Resources, Budapest,* 1954 Report, 184-194, 1955.

Several new devices for water measurements were developed in 1954. A standard recording gage was improved by many important details. A precise gage, accurate and sensitive up to 0.01 mm, was designed with a plastic disk instead of hook or needle. A floating syphon was developed for an uniform water discharge, necessary for the salt-dilution method. S. Kolupaila, USA

3638. Szesztay, K., Empirical method for estimating evapo-transpiration from land areas (in Hungarian), *Res. Inst. for Water Resources, Budapest,* 1954 Report, 72–80, 1955.

The mean annual evapo-transpiration is determined as a mean annual precipitation minus a mean annual runoff. For every particular year, changes in ground water yield are considered. For monthly variations, an empirical diagram by Kuzin was applied.
S. Kolupaila, USA

3639. Lászlóffy, W., Forecasting during the flood (in Hungarian, with French summary) *Víz. Közl.* **37,** 186–203, 1955.

Danube River flood forecasting is based on a well-designed international organization. Significant data from the upper part of the river and from all important tributaries are transmitted to Budapest and immediately elaborated. Local factors, such as breaks of levees, are considered. Results show an accuracy of forecasts more than satisfactory for defense of levees and towns.
S. Kolupaila, USA

3640. Csermák, B., Estimation of flood discharges in small rivers (in Hungarian), *Res. Inst. for Water Resources, Budapest,* 1954 Report, 64–71, 1955.

An empirical formula for maximum discharge of 3% probability is derived as function of the square root of a basin area and a variable factor, represented on a cartogram. Equation is based on 26 basic data and on 120 estimated by analogy.
S. Kolupaila, USA

3641. Szilágyi, J., and Muszkalay, L., Effect of ice cover on river discharge (in Hungarian), *Res. Inst. for Water Resources, Budapest,* 1954 Report, 80–90, 1955.

Correction factor $\varphi = Q_e/Q_o$, used for determination of a winter discharge from the discharge curve for open channel, is studied as function of two arbitrary arguments: (1) a relative discharge $q = 100\,(Q_e - Q_{min}) / (Q_{max} - Q_{min})$, (2) a characteristic factor for every cross section $a = h_m(A)^{1/2}/B\, v_m e_m$, where h_m is average depth, A area of cross section, B surface width, v_m average velocity in open channel, undisturbed by the ice cover, e_m average ice thickness. Values for a varied between 0.3 and 5.7 (in metric units). A diagram gives the values of φ as a function of q and a. Method can be applied for stations with insufficient observational data. S. Kolupaila, USA

3642. Lászlóffy, W., Seventy years of hydrographic service in Hungary (in Hungarian), *Res. Inst. for Water Resources, Budapest,* 1954 Report, 5–35, 1955.

Historical review demonstrates progress in the technique of river investigations in Hungary. Contributions of Hungarian hydrologists to that science are widely known and recognized. A complete bibliography of 89 titles underlines the importance of well-organized work. S. Kolupaila, USA

3643. Lászlóffy, W., and Szilágyi, J., The Danube flood of July, 1954. Results of flood discharge measurements (in Hungarian, with English and French summaries), *Víz. Közl.* **37,** 106–116, 1955.

During unusually high flood, Hungarian Hydrographic Service performed 67 current-meter measurements in 6 stations. River was up to 450 m wide, to 15 m deep, velocities to 2.1 m/sec, water discharge up to 8100 m^3/sec. Velocities were measured at 2-m intervals along verticals. Two examples of cross sections with isotachs are presented. A usual loop of discharge curve due to different slope was obtained. A current meter with heavy body (up to 80 kg, or 175 lb) is required for these conditions. A total runoff during the flood of 5.20 km^3 was determined, representing 43.3% of the rainfall. S. Kolupaila, USA

3644. Surova, N. N., A circular spillway outlet (in Russian), *Gidrotekh. Stroit.* **24,** 7, 38–39, 1955.

Scale-model study of a circular fan-shaped spillway capable of dealing with a normal discharge of 70 m^3/sec (2520 cu ft/sec) and a maximum storm discharge of 240 m^3/sec (8640 cu ft/sec). The study is aimed at the greatest possible dissipation of energy in order to reduce scour down stream.
A. G. Foster, England

3645. Kee, C. F., The backwater curve for channels of various cross-sections, *Civ. Engng., Lond.* **51,** 600, 651–654, June 1956.

3646. Carlson, E. J., and Miller, C. R., Research needs in sediment hydraulics, *Proc. Amer. Soc. civ. Engrs.* **82,** HY2 (*J. Hydr. Div.*), Pap. 953, 33 pp., Apr. 1956.

3647. Anonymous, Outlet works and spillway for Garrison dam, Missouri river, North Dakota, *Wuys. Exp. Sta. tech. Memo.* 2–431, 57 pp. + 16 tables + 30 photographs + 88 plates, Mar. 1956.

Incompressible Flow: Laminar; Viscous

(See also Revs. 3495, 3627, 3636, 3684, 3713, 3715, 3736, 3742, 3748, 3759, 3761, 3770, 3771, 3782)

3648. Shercliff, J. A., Entry of conducting and nonconducting fluids in pipes, *Proc. Camb. phil. Soc.* **52,** 3, 573–583, July 1956.

Theoretical treatment is given to problem of entry of electrically conducting, viscous fluid flowing between parallel planes, or in rectangular pipes, or in circular pipes, into a region with a transverse magnetic field. Approach to steady laminar velocity profile is studied by linearizing equations with Rayleigh approximation adapted to flow with a pressure gradient. Author shows that same linear equations hold in time varying flow if distance $z \rightarrow v_0 t$, where v_0 is initial uniform velocity. Most persistent terms describing decay toward steady velocity are estimated. Magnetic field is found to increase settling distance considerably. In induction flowmeter, author points out that operating conditions are often such that complete settling of velocity profile will not be made before fluid passes electrodes. Finally, estimate of accuracy of this treatment is made by comparing results for vanishing magnetic effects with other known solutions. W. Griffith, USA

3649. Tomotika, S., and Yosinobu, H., The flow of viscous liquid past a flat plate at small Reynolds numbers, *J. Math. Phys.* **35,** 1, 1–12, Apr. 1956.

A second approximation for the skin friction at small Reynolds numbers has been calculated by Piercy and Winny, Davies, and Sidrak, by developing different analyses from each other. No complete agreement can be found among these three expansion formulas, and they differ slightly from each other. The present paper maintains that the relation by Piercy and Winny is correct, whereas the relations by Davies and Sidrak are both erroneous. An analytical proof is given of the authors' contention.
R. C. Binder, USA

3650. Alksne, A. Y., Determination of vortex paths by series expansion technique with application to cruciform wings, *NACA TN* 3670, 40 pp., Apr. 1956.

A series method of determining two-dimensional vortex paths is considered and applied to the computation of vortex positions behind a slender equal-span cruciform wing at any angle of bank as a function of the distance behind the trailing edge. Calculated paths are shown for four bank angles. For a bank angle of 45°, comparison is made with the results of a closed expression given in *NACA TN* 2605. For other bank angles, water-tank experiments provide qualitative comparison. Satisfactory agreement is found a sufficient distance downstream to include most practical missile-tail positions. The interference forces on an equal-span interdigitated cruciform tail behind a slender equal-span cruciform wing are calculated for four angles of bank from the vortex positions found by use of the series.

From author's summary by S. B. Berndt, Sweden

3651. Tanoda, S., Experimental investigation of the wakes behind cylinders and plates at low Reynolds numbers, *J. phys. Soc. Japan* **11,** 3, 302–307, Mar. 1956.

Wakes of circular cylinders were very carefully investigated in the Reynolds number range in which wake vortexes and oscillations begin to form. The model was moved through still water with suspended aluminum dust to observe the wake motion photographically. Also, models coated with condensed milk were used to determine the positions of separation and boundary line of the vortexes.

From the author's measurements, the twin vortexes appear at Reynolds numbers above $Re = 5$. The extention of the twin vortexes against Re is given. Above $Re = 30$ the wake begins to oscillate some distance downstream. The plot of frequency against Re is also given. For $Re > 45$, the twin vortexes become unstable and the Karman vortex street begins to form. Wakes behind flat plates parallel to the flow show the beginning of oscillation about $Re = 700$ (Re from plate length). N. Scholz, Germany

3652. Domm, U., On the stability of vortex streets, *AF tech. Rep.* AFOSR-TN-56-27, 22 pp., 1956.

A survey of the present state of the stability theory of vortex streets, including description of interesting results that author intends to publish in several papers. Some concluding remarks are given on the influence of viscosity and of compressibility.

H. Görtler, Germany

3653. Brun, E. A., Castel, L., and Faulmann, D., On a peculiar case of oscillation of vortexes (in French), *Publ. sci. tech. Min. Air, France TN* 58, 25 pp., 1956.

Air is discharged axially from a narrow duct approximately centrally disposed in a wide flat rectangular duct with a closed end. The air reverses direction and escapes through the open end either side of the inlet duct.

Cine records and outline flow patterns sketched show the development of symmetric vortexes each side of the jet at low velocities. As the velocity is increased, the vortexes become unstable (rather in the manner of the von Karman "train" behind a cylinder) and the jet is swept periodically across the width of the flat rectangular duct.

Graphs are shown relating the period of jet oscillation to velocity for various dimensions of duct and positions of the small duct within the large. For certain dimensions, frequency is proportional to velocity and inversely proportional to the distance the short tube protrudes into the large duct. If pushed in almost to the closed end, the periodic vortex motion ceases. Graphs also show the frequency variation as the jet is displaced either side of the center position.

The report ideally sets out the experimental details and results and is impressive as a concise investigation of the phenomena. Further work could make the general representation more valuable.

R. Culver, Australia

3654. Dolapchiev, Bl., Approximate determination of vortex resistance (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **98,** 5, 743–746, Oct. 1954.

Applications of the well-known von Kármán formula for vortex resistance meet with some difficulties due to the fact that two of the six quantities determining the vortex resistance should be found experimentally. Kosmodemlianski introduced further assumptions allowing one to determine the circulation theoretically, at least with some approximation. The present paper deals with the question: For what kind of rising vortexes and following vortex configuration is the Kosmodemlianski hypothesis sufficiently adequate? J. Beránek, Czechoslovakia

3655. Dolapchiev, Bl., On the stability and oblique flow of two-parameter vortex streets (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **98,** 3, 349–352, Sept. 1954.

Author gives a simple derivation of the stability condition ($\sin k\pi = \sin \lambda\pi$, where $k = h/l$, $\lambda = d/l$) for two-parameter (asymmetric) vortex streets, which leads directly to the instability of symmetric stress and to the condition for stability of staggered streets for $\lambda = 0$ and $\lambda = 1/2$. Author claims the interpretation of the flow of a two-parameter vortex street given in Sommerfeld's "Lectures on theoretical physics" is incorrect. The correct interpretation should be that the axis of symmetry of an infinite sheet maintains a constant direction—the direction of the free stream flow—but is displaced parallel to itself rather than at an angle to the free-stream direction as Maier [*ZAMM* **20,** 1940] predicts. Attempts to verify latter statement experimentally at the Budapest Aerodynamic Institute failed.

M. D. Friedman, USA

3656. Shimose, T., On theoretical studies of the vortex motion of a perfect fluid —I., *Ochanomizu Univ., Tokyo, Natur. Sci. Rep.* **2,** 62–78, Nov. 1951.

Some of the consequences of Clebsch's transformation of the equations of inviscid fluids are studied. In particular it is shown that the equation of vorticity transport for steady, incompressible, two-dimensional flow can be reduced to a nonlinear equation of first order in one of Clebsch's variables.

H. G. Loos, USA

3657. Kiselev, A. A., Unsteady flow of a viscous incompressible fluid in a bounded three-dimensional region (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **106,** 1, 27–30, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 5 pp.).

Author considers the problem of determining the velocity vector in a bounded three-dimensional domain and finite time interval, satisfying the usual Navier-Stokes' equations, vanishing at wall and having a given initial velocity distribution. Define $\vec{V}$ as the generalized solution if (1) $\vec{V}$ belongs to $L_2(Q_l)$, where Q_l is the bounded space-time domain; (2) the first and second derivatives of $\vec{V}$, generalized in the Sobolev sense, exist and also belong to $L_2(Q_l)$; and (3) $\vec{V}$ satisfies the continuity equation, the boundary and initial conditions, and, instead of the differential equation, the integral identity:

$$\int_{Q_l} \left\{ \vec{V}_t \vec{\phi} - \sum_{k=1}^{3} V_k \vec{V} \vec{\phi}_{x_k} + \nu \sum_{k=1}^{3} \vec{V}_{x_k} \vec{\phi}_{x_k} - \vec{f}\,\vec{\phi} \right\} dx\, dt = 0$$

for all $\vec{\phi}$ with the same properties as $\vec{V}$. Here $\vec{f} = \vec{f}(x, t)$, a given acceleration field such as gravity, and ν is the coefficient of kinematic viscosity. Then uniqueness and existence theorems for the solution $\vec{V}$ are established by using Galerkin's method.

S. F. Shen, USA

3658. Hurley, D. G., The effect of a small laminar separation bubble on the potential flow past an aerofoil, *Aero. Res. Labs.,*

Melbourne, *Austral. Aerodyn. Note* 148, 14 pp. + 7 figs., Oct. 1955.

The problem of the laminar separation bubble is treated as an interaction between the boundary layer and an external potential flow. This note represents a first step toward the solution.

First, simplified expressions (neglecting the curvature) are derived for finding the change in pressure distribution due to a small bump and for finding the shape of the bump which produces a specified change in the pressure distribution.

Experimental boundary-layer measurements on a NACA 66_3-018 airfoil were used to compute the displacement thickness, and this was used as the bump to compute the change in pressure distribution. It is claimed that the agreement with experiment is satisfactory after an "adjustment" to bring the results with no bump together.

W. Squire, USA

3659. **Döge, R., Calculation of potential flow through a cascade according to Howell's method** (in German), *Maschinenbau-Technik* 4, 12, 635–647, Dec. 1955.

Flow is determined by a conformal mapping of the cascade of identical two-dimensional airfoils onto a single circle. Howell's exact method [*Phil. Mag.* (7) **39,** Dec. 1948] is followed to obtain an almost circular contour. This last is then mapped onto the circle using a few terms of the exact infinite series. Coefficients are determined by collocation so that precision is determined by number of points fitted. Measures of the error are given.

C. M. Ablow, USA

3660. **Liu, S.-W., The laminar boundary layer of yawed cylinders with variable section,** *Cornell Univ., School aero. Engng.* 44 pp. + 7 tables + 19 figs., Sept. 1955

Starting from the results of laminar boundary-layer calculations for infinite yawed cylinders, extension is made to obtain analogous results for yawed bodies of slowly varying, similar cross sections. Both the external and internal flows are expanded in powers of the local taper and are expressed in terms of nondimensional similarity variables. Velocity components of successive orders of magnitude are computed by a procedure similar to that by which the infinite cylinder results have been obtained. The equations are solved for a symmetric body whose external flow is of the type that gives separation of the chordwise flow. The results are obtained by numerical methods. It is shown that the relative position of the separation of the chordwise flow remains essentially unchanged by the taper. The velocity profiles and the limiting streamlines are modified. The departure from infinite-cylinder results at the same relative chordwise position is not large for yawed bodies.

From author's summary by M. H. Bertram, USA

3661. **Landweber, L., and Winzer, A., A comparison of the added masses of streamlined bodies and prolate spheroids,** Stevens Inst. Technol., Experimental Towing Tank, Rep. 572, 12 pp., June 1955.

A method of estimating the added mass coefficient of a streamlined body is to replace the true coefficient by the coefficients of an ellipsoid of revolution with the same fineness ratio as the body. Authors compare the three coefficients for plane motion found in this way with exact values computed on Univac at the David Taylor Model Basin. Comparison is reasonable for all but the longitudinal coefficient. An approximate formula found by a least-square fit of the exact values for a number of body shapes is given for the latter coefficient.

The revised method gives a quick and reasonably accurate method of estimating virtual mass coefficients.

R. C. Roberts, USA

3662. **Miesse, C. C., Application of droplet ballistics theory to experiments of Ingebo,** *Jet Propulsion* **25,** 1, p. 36, Jan. 1955.

Validity of theory of droplet ballistics is applied to the experimental data of Ingebo. It is found that (1) drag coefficient for an evaporating droplet varies inversely with its Reynolds number, (2) the variable evaporation rate can be represented by its mean value over an interval of time or space.

K. J. DeJuhasz, Germany

3663. **Golitzine, N., The spraying of liquids,** *Nat. Res. Counc. Canad., Div. mech. Engng. Quart. Bull.* 14 pp. + 10 figs., Jan.–Mar. 1954.

Spraying of liquids enters into many fields of science and industry, as well as into medicine, agriculture, war, meteorology, and everyday life. Paper surveys application of sprays. Types of sprayers include straight jet, swirl nozzles, pneumatic spray nozzles, rotating sprayers, combinations of sprayer types. Spray characteristics are velocity, shape, penetration, rate of flow, distribution of droplet size. Methods used to study the previously listed characteristics include photography, sampling, their difficulties and tricks used. Choice of sprayers for a given purpose is indicated. Reproducibility of sprays, as in successive injections into a diesel engine, is mentioned.

This is a good orientative article, giving a bird's-eye view of spray science and technology, which provides an instructive introduction for deeper and more detailed studies.

K. J. DeJuhasz, Germany

3664. **Davidson, I. M., The jet flap,** *J. roy. aero. Soc.* **60,** 541, 25–50, Jan. 1956.

3665. **Laitone, E. V., Comments on limiting pressure on hydrofoils,** *J. appl. Phys.* **26,** 12, 1519–1520, Dec. 1955.

3666. **Guman, W. J., On the decay of a flow nonuniformity,** *J. aero. Sci.* **22,** 12, p. 869 (Readers' Forum), Dec. 1955.

Compressible Flow, Gas Dynamics

(See also Revs. 3652, 3700, 3703, 3724, 3726, 3729, 3733, 3751, 3754)

3667. **Shapiro, A. H., The aerothermopressor,** *Engineer, Lond.* **201,** 5234, 517–518, May 1956.

Resume of the principles of the aerothermopressor, presented as the introduction to the 1956 Akroyd Stuart Memorial Lectures at the University of Nottingham devoted to the discussion of this device. Its development was described previously in a comprehensive paper by A. H. Shapiro, K. R. Wadleigh, B. D. Gavril, and A. A. Fowle [*ASME Trans.* **78,** 3, 617–653, Apr. 1956].

A. K. Oppenheim, USA

3668. **Grinnell, S. K., Flow of a compressible fluid in a thin passage,** *Trans. ASME* **78,** 4, 765–771, May 1956.

Author presents a simplified analytical method for the pressure distribution and weight flow rate in thin passages. The "Adiabatic constant area flow comprehensive analysis" given by A. H. Shapiro ["Flow of compressible fluid"—notes for course 2.491, Dept. Mech. Engng., Mass. Inst. Tech.] is outlined. The discrepancy in this method is the trial-and-error solution necessary in computing the stream properties and flow rate. For this, author neglects the momentum effects, which leads to explicit relationships for pressure distribution and flow rate.

Author presents experimental investigation to substantiate the validity of the analytical work. Experimental pressure distributions agree within 10% and experimental weight flow rates agree within 50% of the predicted values based on the simplified theory.

Reviewers feel report is valuable for designs of pneumatic mechanisms where small h/L values and weight flow rates are encountered. For fractional cases where heat transfer plays an important role, the adiabatic solution may be close to actual operating characteristics.

K. J. Schoenherr and C. E. Pauletta, USA

3669. Byrd, P. F., Theoretical wave drag of shrouded airfoils and bodies, *NACA TN* 3718, 40 pp., June 1956.

Formulas are derived, by linear theory, for the wave drag of shrouded airfoils and bodies. A shrouded airfoil has flat plates above and below the surface, while the shrouded body of revolution is one surrounded by a hollow cylindrical shell. Classes of shrouded bodies and airfoils are described for which the wave drag would theoretically be zero. Since viscous effects are not considered, the additional friction drag of the shrouds is not assessed. Furthermore, the linear theory treatment results in assuming that configurations actually operate as shock-free isentropic diffusers, a condition which is difficult to establish in practice.

L. H. Schindel, USA

3670. Maslen, S. H., and Moore, F. K., On strong transverse waves without shocks in a circular cylinder, *J. aero. Sci.* **23,** 6, 583–593, June 1956.

3671. Rogers, M. H., The propagation and structure of shock waves of varying strength in a self-gravitating gas sphere, *Proc. roy. Soc. Lond.* (A) **235,** 1200, 120–136, Apr. 1956.

Motion of a spherical symmetric shock wave of varying strength in a gas whose density varies with distance from the center is studied, starting from McVittie's equations [*Astronom. J.* **59,** p. 173, 1954] and expanding in ascending powers of the inverse square of the Mach number. Total (kinetic, thermal, and gravitational) energy in a sphere bounded by the shock front is assumed equal to the original thermal and gravitational energy in a sphere of the same radius, plus the energy released by the explosion. First approximation is calculated for very strong shock waves. Numerical results are presented. For certain density distributions the blast wave consists of a thin shell of gas while the remainder of the original sphere is left intact.

G. Moretti, Argentina

3672. Legendre, R., Subsonic flow of a perfect fluid around a cone of revolution (in French), *Rech. aéro.* no. 50, 9–11, 1956.

Potential function of subsonic flow past a cone of revolution is composed by two homogeneous terms of different degrees. The first term contains the Legrende function of first kind $P_n(x/R)$, and gives a flow with axial symmetry (zero angle of attack); the second term contains the derivative of the Legendre function and delivers an additional flow with symmetry to the plane $x = 0$ (small angle of attack). In the case of zero incidence, there is a stagnation point on the surface of the cone. The practical application of the paper is the study of behavior of subsonic flow (kind of singularity) in the neighborhood of the head of an airship.

R. Sauer, Germany

3673. Gates, S. B., Notes on the transonic movement of wing aerodynamic centre, *Aero. Res. Counc. Lond. Rep. Mem.* 2785, 22 pp. + 2 tables + 16 figs., 1955.

Paper is essentially a survey of results of linearized theory for subsonic and supersonic regimes; the transonic regime is not considered in any detail. The survey was made in 1948 and a few footnotes were added in 1952. Reviewer believes that the value of this paper as a source of data will be marginal to those with access to relevant information (much of it classified) amassed since then. However, the paper has undeniable and permanent educational value. It is interesting to note that the few experimental data then available showed fortuitously somewhat better agreement with linearized supersonic theory than more recent experimental data indicate.

A. D. Young, England

3674. Broer, L. J. F., Simple wave solutions of the transonic equation, *J. aero. Sci.* **23,** 3, p. 287 (Readers' Forum), Mar. 1956.

By determining the characteristic relations in the hodograph, the transonic equation of Cole ["Problems in transonic flow," Ph.D. Thesis, California Institute of Technology, 1949] is reduced to a first-order equation for which the general solution represents a simple wave. Solution is, of course, valid only for supersonic portion of transonic regime. It is shown that Morgan's result [*J. aero. Sci.* **22,** 8, 573–575, Aug. 1955], which is analogous to the Prandtl-Meyer solution of nonlinear supersonic flow, is a special case of this general solution.

P. F. Maeder, USA

3675. Takami, H., A study of the compressible flow past a Cherry profile, *J. phys. Soc. Japan* **11,** 2, 145–154, Feb. 1956.

The compressible flow past a profile calculated by T. M. Cherry [*Proc. roy. Soc. Lond. (A)* **196,** 1949; AMR **2,** Rev. 1165] is studied for four free-stream Mach numbers by means of the Karman-Tsien, M^2-expansion, and the Meksyn-Imai methods. The first two of these are well known. The third was proposed by Meksyn [*Proc. roy. Soc. Lond. (A)* **220,** 239–254, 1953; AMR **7,** Rev. 2907] and has been modified by Imai (unpublished). Imai's treatment is presented briefly here; it consists essentially of expressing the coefficients of Meksyn's theory as expansions in powers of M. The results of all three methods fail to reproduce even qualitatively the type of pressure distribution that Cherry obtained by the hodograph theory when the stream Mach number is supercritical. Author suggests that this may mean that the hodograph solution is a special one not related to those calculated for the same body at other Mach numbers.

Since these cases are supercritical, i.e., the flow fields have both subsonic and supersonic regions, it is doubtful that the solutions obtained by the M^2-expansion and Meksyn-Imai methods are meaningful, because of uncertainties of convergence. As to the solution given by the Karman-Tsien method, it is surely unreliable because this method deals exclusively with purely subsonic flow. Therefore, reviewer believes that author's speculations on the question of existence of mixed potential flows are unfounded.

Y. H. Kuo, USA

3676. Oswatitsch, K., Extreme speeds and thermal behavior in supersonic flow (in German), *Z. Flugwiss.* **4,** 3/4, 95–108, Mar.–Apr. 1956.

General article briefly surveys various aspects of hypersonic flight which involve high temperatures. Shock tubes, rockets, air-breathing propulsive devices, the drag problem, and the thermodynamic properties of gases at temperatures up to ionization are discussed from a broad viewpoint. Discussion is lucid throughout.

D. R. Chapman, USA

3677. Trimpi, R. L., An analysis of buzzing in supersonic ram jets by a modified one-dimensional nonstationary wave theory, *NACA TN* 3695, 72 pp., July 1956.

Cold ramjet buzz is analyzed by method of characteristics for unsteady quasi-one-dimensional flow, starting from experimentally determined flow conditions. Computed pressure-time curves agree closely with experimental records. Simulation of combustion by area contraction in cold-flow models, as suggested by form of unsteady-flow equations, is also discussed.

Paper is of interest despite uncomfortable lack of clarity in explanation of some of the assumptions which are made to reduce the computational labor. Quasi-one-dimensional approach is more realistic than Helmholtz-resonator method of analysis, in view of ramjet geometry, and further study along these lines may be expected to yield useful information and ramjet design criteria.

J. V. Foa, USA

3678. Graham, M. E., Optimum thickness and lift distribution for a fuselage in the presence of a prescribed wing system, *Douglas Aircr. Co. Rep.* SM-19615, 8 pp., Mar. 1956.

A drag formula of Hayes is utilized to obtain a generalized supersonic "area rule" in terms of sources, lift, and side-force singularities. The rule is applicable to configurations such as "non-midwing" monoplanes and to ring wings for which the thickness, lift, and side-force distributions do not act independently in producing drag. Simple examples of optimum fuselage source distributions and optimum fuselage lift distributions are presented.

From author's summary by A. M. Kuethe, USA

3679. Hartnett, J. P., and Eckert, E. R. G., Experimental study of the velocity and temperature distribution in a high velocity vortex type flow, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prep. 9, 20 pp.

Paper summarizes experimental distributions of pressure, temperature, and velocity in a "vortex tube" with zero flow at cold outlet. Data are given at small radial increments and several axial sections on a three-inch diameter unit. Data appear consistent and of high quality; both static and stagnation temperatures are shown as well as axial flow components.

Brief presentation is made of equations for several basic viscous flow patterns, including uniform flow along a rotating tube.

C. D. Pengelley, USA

3680. Hirschfelder, J. O., and Dahler, J. S., The kinetic energy of relative motion, *Proc. nat. Acad. Sci. Wash.* **42**, 6, 363-365, June 1956.

Equations are presented for expressing the kinetic energy of a system of N particles in terms of a set of coordinates relative to the kinetic energy of the center of mass. Authors point out that these coordinates should be useful in molecular collision problems and molecular rotation-vibration problems. Their principal use, however, will probably lie in the prediction of the variation of chemical reaction rates with isotopic masses, since the zero-point energy in the activated complex and also the transmission coefficient depend rather sensitively on the masses which appear in the relative coordinates.

M. Gerstein, USA

3681. Schaaf, S. A., Aerodynamics at very high altitudes, *Jet Propulsion* **26**, 4, 257-250, Apr. 1956.

Experimental results from the Berkely low-density tunnel are described. These results were obtained in the "slip flow" region or the range of flow conditions corresponding to flight at altitudes from 20 to 80 miles. Data are presented for the cone drag, flat-plate lift, base pressure on cone cylinders, cone heat transfer, and boundary layer in the leading-edge region of a flat plate. Where possible, comparisons of the data are made with existing theories.

The aerodynamic and heat-transfer characteristics of these basic shapes are, in general, quite different from the corresponding values obtained in the continuum region. Author concludes that theoretical analyses are not yet sufficiently precise to provide an adequate basis for determining how much of this difference is ascribable to noncontinuum phenomena such as slip and how much to low Reynolds number supersonic continuum flow behavior.

G. J. Nothwang, USA

3682. Byrd, P. F., Theoretical pressure distributions for some slender wing-body combinations at zero lift, *NACA TN* 3674, 39 pp., Apr. 1956.

For slender wings, the perturbation potential consists of two parts, the first independent of the Mach number and a harmonic in the transverse plane, the second dependent on the cross-sectional area and a function of x and M only. Pressure coefficient is used in the form $C_p(x,y,0) = -2u/U_0 = (v^2 + u^2)/U_0^2$, following Heaslet and Lomax [AMR **6**, Rev. 3170]. Their method is modified and extended to obtain C_p on the combination of a wing with a cylindrical body, using the Joukowski transformation. Analyzing the results of C_p due to thickness, a theoretically finite C_p can be obtained even at $M = 1$ if the gradient of the cross-sectional area in the yz plane vanishes identically. This leads to bodies with indentations following the area rule where the maximum perturbations are reduced. Combinations of indented, nearly cylindrical bodies with constant-chord swept wings show smooth isobars similar to the ones for the wing alone (two-dimensional), a very remarkable result. Isobaric maps are shown and discussed for wings alone and for wing-body combinations in subsonic and supersonic flow.

G. R. Graetzer, USA

3683. Lush, P. E., and Cherry, T. M., The variational method in hydrodynamics, *Quart. J. Mech. appl. Math.* **9**, 1, 6-21, Mar. 1956.

Steady irrotational isentropic flow of a compressible fluid with prescribed time rate of normal mass-flow per unit area over the boundary is shown to depend on the stationary value of one or the other of two integrals given by Bateman [*Proc. nat. Acad. Sci.* **16**, p. 816, 1930]. One is a function of velocity potential, the other of stream function. In the latter case, the method can be extended to include irrotational flow in three dimensions, and, by appropriate choice of a given function, any case of steady plane rotational motion. Flow past an airfoil is exemplified and a Rayleigh-Ritz procedure is described for approximate numerical evaluation. Results for flow past a circular cylinder are in good agreement with those obtained by Imai, Wang, Taylor and Sharman, and by linearized theory.

Present paper extends the work of Wang [AMR **2**, Rev. 210] which was limited to polytropic gas flow with $\gamma/(\gamma-1)$ integral. A strict treatment is given of the convergence problem arising from the infinite extent of the flow field. It is claimed that the variational procedure can be applied also to supersonic and transonic problems.

S. Kirby, England

3684. Behrbohm, H., Some integral transformations between two-dimensional and three-dimensional axially symmetrical flows (in German), *Z. Flugwiss.* **4**, 1/2, 40-44, Jan./Feb. 1956.

Two types of integral transforms are presented for expressing velocity potential and stream function of axisymmetric flow by two-dimensional harmonic or wave functions. The first type is equivalent to the classical formula expressed in a different form [Lamb, "Hydrodynamics," 6th ed., p. 119]. Author shows that velocity potential and stream function in axisymmetric flow are related to the velocity components normal to and in the free-stream direction, respectively, in two-dimensional flow. The second transform is a new one, containing logarithmic factor in the integrand. Author suggests the possibility of operating with cylindrical sources in this case, but application to the actual problem is not given.

F. Tamaki, Japan

3685. Spense, D. A., and Routledge, N. A., Velocity calculations by conformal mapping for two dimensional aerofoils, *Aero. Res. Counc. Lond. curr. Pap.* 241, 41 pp. + 7 figs., 1956.

A symmetric airfoil in a $z = x + iy$ plane is mapped into a slit in a $\zeta = \xi + iy$ plane. For the shift $\xi - x$ of the airfoil points, an integral equation involving principal values is obtained, which is solved by iteration. Integral equation is simplified by introduction of a thickness parameter ε and retaining second-order terms.

Introducing Fourier expansions for the contour function $\{x = 1/2 (1 + \cos\theta)\}$, Fourier series for the slope is found. The first-order term of the shift then follows by aid of the conjugate Fourier series. For the second-order term, quadratic expressions in the

Fourier coefficients are derived and a computational routine is given. The velocity distribution at an angle of incidence is given, as well as a calculation method for the velocity of the surface near the trailing edge. Modification of method for cambered air foils and for the inverse problem is outlined. Reviewer notes that method is closely related to Goldstein's method and also to reviewer's method [AMR **5**, Rev. 843]. Computation routine presented here is, however, much more simple than that of reviewer.

R. Timman, Holland

3686. Domm, U., Fabian, H., Wehrmann, O., and Wille, R., Contributions on the mechanics of laminar-turbulent transition of jet flow, *AF tech. Rep.* AFOSR-TR-56-9, 32 pp. + 27 figs., Nov. 1955.

Authors have made an analytical and experimental study of free jet flow with emphasis on the phenomena occurring in the first few diameters downstream from the nozzle. In the analytical treatment, the annular vortex system is idealized as a plane system in an ideal fluid. An equation for the trajectories is derived and it is shown that the vortex system is an unstable equilibrium.

Experimental studies were conducted by drawing atmospheric air into a cylindrical chamber, 2 m in diameter and 6 m long, through a nozzle. Nozzles of 1.0, 2.5, 5, and 10-cm diam were used. Mean-velocity and velocity-fluctuation measurements were made by a conventional hot-wire technique. The hot wire itself was 1.5 microns in diam and 1 mm long. It was located on a probe mechanism within the chamber. For mean-velocity measurements a Wheatstone bridge circuit was used, and for velocity fluctuations an oscilloscope was employed in conjunction with constant current operation of the hot wire. Fluctuation-frequency and frequency-spectrum measurements were also made using a frequency meter and a harmonic wave analyzer.

Experimental mean-velocity profiles are shown in several planes normal to the jet axis at distances up to four nozzle diameters downstream from the nozzle. The results of velocity-fluctuation measurements are correlated with the nozzle efflux Reynolds number in the range from 0 to 25,000. The growth in the amplitude of the fluctuations along the jet is very clearly shown. Some preliminary results are reported on the measurement of the frequency of fluctuations of various amplitudes.

T. J. Connolly, USA

3687. Barenblatt, G. I., and Krylov, A. P., Elastic-plastic processes in percolation (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 2, 5-13, Feb. 1955.

This work defines the problem of the unsteady percolation of compressible liquids in a porous, nonelastic medium. Such a medium is characterized by different relationships of the porosity due to the effects of loading and unloading. This problem is related to a decrease and restoration of pressure of a liquid in a packed bed.

From authors' summary by R. M. Evan-Iwanowski, USA

3688. Dunne, B., and Cassen, B., Velocity discontinuity instability of a liquid jet, *J. appl. Phys.* **27**, 6, 577-582, June 1956.

The instability of a high-speed liquid jet with a velocity which has a transient rise followed by a linear decay with time is studied experimentally and theoretically. The jet is produced experimentally by subjecting a liquid reservoir to a shock-wave pressure. Using shadowgraph technique, in an interval of thirty microseconds four successive quarter-microsecond exposures were taken using jets of water and ethanol in external atmospheres of air and helium. It is found theoretically that a velocity discontinuity is advanced through the jet at a velocity which is the mean of the instantaneous particle velocities immediately in front of and behind the discontinuity. The discontinuity consists of a thin disk of liquid normal to the jet axis. Nodules previously observed on high-speed liquid jets [see previous work of authors, AMR **7**, Rev. 3261] can be explained by this mechanism. The transient pressure generator and the shadowgraph setup are shown schematically. Four-frame shadowgraphs are given, showing development of disks.

K. J. DeJuhasz, Germany

3689. Holmquist, C. O., and Rannie, W. D., An approximate method of calculating three-dimensional compressible flow in axial turbomachines, *J. aero. Sci.* **23**, 6, 543-556, June 1956.

3690. Benson, R. S., Unsteady compressible flow with variable specific heats, *J. roy. aero. Soc.* **60**, 545, 347-348 (Technical Notes), May 1956.

Subject of this paper has been treated previously by reviewer, AMR **2**, Rev. 1427. Present method uses variables which may appear more natural to the aerodynamicist.

G. Guderley, USA

3691. Miles, J. W., A first-order formulation of the unsteady supersonic flow problem for finite wings, *J. aero. Sci.* **23**, 6, 578-582, June 1956.

The problem has been solved for strictly supersonic trailing edges [AMR **4**, Revs. 78, 315, 333]. By appropriate extension of the transformation, author removes the trailing-edge restriction as suggested by a result in Evvard [AMR **4**, Rev. 3310]. The determination of the pressure distribution over a thin, finite wing in supersonic flow due to a prescribed incidence that varies slowly in time (so that the square of the reduced frequency may be regarded as negligible) is reduced to a pair of steady-flow problems. The first of these is the steady-flow problem for the given planform with modified incidence. The second corresponds to a modified steady-flow problem in which the wake is neglected and the potential is required to vanish along subsonic trailing edges. In the absence of subsonic trailing edges the solution to the second problem follows directly from the solution to the first problem, and the results then reduce to those previously known.

From author's summary by G. R. Graetzer, USA

Wave Motion in Fluids

(See also Revs. 3635, 3677)

3692. Brunn, P., Destruction of wave energy by vertical walls, *Proc. Amer. Soc. civ. Engrs.* **82**, WW 1 (*J. Wwys. and Harbors Div.*) Pap. 912, 13 pp., Mar. 1956.

Several methods for controlling wave heights within harbors are briefly summarized, with particular attention paid to the use of phase displacements of reflected waves. Described in detail is the use of a permeable wall of spaced piles to reduce heights of waves reflected from a nearby vertical wall. Method for determining energy loss through this type of permeable wall is discussed.

G. Kulin, USA

3693. Wiegel, R. L., and Beebe, K. E., The design wave in shallow water, *Proc. Amer. Soc. civ. Engrs.* **82**, WW 1, (*J. Wwys. and Harbors Div.*) Pap. 910, 21 pp., Mar. 1956.

A method is discussed whereby solitary wave theory can be adapted to conservatively approximate the internal velocities beneath the crest of a breaking shallow-water oscillatory wave. The maximum theoretical solitary wave is used, and its centerline velocity profile is plotted from the oscillatory-wave surface downward in terms of the velocity-to-celerity ratio. The resulting ve-

locity profiles are shown to compare favorably with observed profiles of breaking oscillatory waves, if the latter profiles are plotted as velocity-to-measured-crest speed ratios.

G. Kulin, USA

3694. Ralls, G. C., Jr., A ripple tank study of wave refraction, *Proc. Amer. Soc. civ. Engrs.* **82,** WW 1, (*J. Wwys. and Harbors Div.*) Pap. 911, 19 pp., Mar. 1956.

The applicability of Snell's refraction law was investigated on beach slopes of 1:20, 1:40 and 1:60, with angles of beach orientation of 15, 34, and 50 degrees. Experiments were conducted at several water depths in a 20-ft × 4-ft × 5-in. ripple tank with wave periods from 0.15 to 0.6 seconds. Wave crest shapes were obtained by photographing a shadow screen on which light refracted through the crests was focused. Snell's law was essentially verified in the range tested.

G. Kulin, USA

3695. Neumann, G., On the dynamics of wind-driven ocean currents, New York Univ., Coll. Engng., Meteor. Paps. **2,** 4, 33 pp., Aug. 1955.

Author includes spherical shape of earth, average vertical density stratification, and variable depth of lower boundary of circulation system. In stratified ocean the lower boundary is taken as the depth of layer of no motion. Equations are developed in which this variable depth plays an important part in the resulting analysis. Author finds that, if the layer of no motion varies as the sine of the latitude, the effect on the circulation of the variation of the Coriolis parameter with latitude is eliminated. Author cites measurements of depth of layer of no motion by A. Defant which indicate such a variation. Reviewer feels that there is some question concerning Defant's analysis and that other estimates of depth of no motion do not indicate such a variation [e.g., G. H. Jung, "Heat transport in the North Atlantic Ocean," Texas A & M Res. Foundat. Tech. Rep. , Reference 55-34T, Aug. 1955]. The question of the westward intensification of wind-driven circulations in the northern hemisphere is left open.

Some simple systems are presented and author states that analytical solution for the whole ocean will be done by numerical integration.

W. P. Elliott, USA

3696. Barenblatt, G. I., Problems in pressure restoration and discharge wave propagation in elastic-plastic percolation processes (in Russian), *Izv. Akad. Nauk. SSSR Otd. tekh. Nauk* no. 2, 14-26, Feb. 1955.

The relationships, tables, and graphs obtained as a result of an analysis conducted in the this paper permit an effective computation of the distribution of pressure as well as the establishment of the laws of propagation of the wave front due to the unloading at the unsteady percolation of a liquid in a nonelastic porous medium.

From author's summary by R. M. Evan-Iwanowski, USA

Turbulence, Boundary Layer, etc.

(See also Revs. 3686, 3714, 3737, 3766, 3767, 3768)

3697. Reid, W. H., Two remarks on Heisenberg's theory of isotropic turbulence, *Quart. appl. Math.* **14,** 2, 201-204 (Notes), July 1956.

The constant K that appears in Heisenberg's theory of turbulence [AMR **2,** Rev. 774] has hitherto been believed to vary substantially with the Reynolds number. Author now shows that this belief is largely unfounded and that one of the criticisms of Heisenberg's theory is thus eliminated.

I. Proudman, England

3698. Tollmien, W., Spectrum of homogeneous turbulence (in German), *Z. Flugwiss.* **4,** 5/6, 195-198, May/June 1956.

Known relations for the spectral tensor of homogeneous incompressible turbulence are derived in a straightforward and clear fashion from the starting point of the Fourier decomposition of the velocity vector.

L. M. Grossman, USA

3699. Batchelor, G. K., and Proudman, I., The large-scale structure of homogeneous turbulence, *Phil. Trans. roy. Soc. Lond.* (A) **248,** 949, 369-409, Jan. 1956.

Paper treats in detail the kinematics and dynamics of homogeneous turbulence associated with the large-scale components that predominate in the final stages of decay.

The results of Proudman and Reid [AMR **8,** Rev. 1442] on the divergence of the triple velocity correlation for large separations in isotropic turbulence for a particular probability distribution, have called into question the basic kinematical assumption of previous studies that all velocity cumulants in homogeneous turbulence are exponentially small for large separations. It is shown herein that the fallacy in the older assumption resides in the neglect of the restriction on the possible kinematical structures of the large-scale turbulence by the dynamical processes taking place. Specifically, the effect of the local pressure which depends on the entire velocity distribution in an unbounded field of turbulence is such as to generate power law forms of the velocity correlation tensors for large separations.

In seeking asymptotic forms of velocity cumulants relevant to grid-generated turbulence which are dynamically invariant, authors are led to postulate a virtual time origin t_o at which integral moments of the velocity cumulants converge. The power law asymptotic forms of the velocity cumulants developed by the action of the fluctuating pressures subsequent to t_o are derived by a consideration of initial time derivatives, as well as the asymptotic forms of the terms in the dynamical equation expressing the rate of change of the velocity covariance.

An application of the foregoing hypothesis to the final period of decay yields the result that the energy decays as $(t-t_o)^{-5/2}$, in accord with experiment.

Results are specialized to the case of isotropic homogeneous turbulence in a concluding section.

L. M. Grossman, USA

3700. Reshotko, E., Heat transfer to a yawed infinite cylinder in compressible flow, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prep. 13, 16 pp.

The steady boundary layer on an infinite yawed cylinder is considered. It is shown that if the main stream is $\propto x^m$, the temperature of the cylinder is constant, the Prandtl number is unity, and the viscosity is proportional to the absolute temperature, then the governing differential equations may be reduced to a pair of ordinary differential equations. These are solved when $M = 1$ for various values of the Mach number and the temperature at the surface of the cylinder.

K. Stewartson, England

3701. Hammerlin, V. G., Contribution to the theory of instability of three-dimensional boundary layer (in German), *ZAMP* **7,** 2, 156-164, 1956.

In the case of large wave lengths, a refined treatment of the three-dimensional instability of laminar boundary layers is made possible by taking into account a further term of the differential equations of the instability. The improved curve of the Görtler parameter $Re\ (\vartheta/R)^{1/2}$ for neutral disturbances has a minimum with an instability wave length approximately equal to 19δ, Re, ϑ, R, and δ being, respectively, the Reynolds number, momentum thickness, radius of curvature of the wall, and boundary-layer thickness. Author's previous results [AMR 9, Rev. 790] are not changed essentially; especially the critical values of the Görtler parameter

are confirmed and also the fact that the critical wave length is large. From author's summary by Y. H. Kuo, USA

3702. Clauser, F. H., The turbulent boundary layer, pp. 1–51, Advances in Applied Mechanics. Vol. IV. (Dryden, H. L., von Karman, T., and Kuerti, G., editors), New York, Academic Press, Inc., 1956.

Author has written a long and very interesting account of recent advances in our understanding of trubulent boundary layers, including a considerable amount of original work. In general, his attention is confined to the distributions of mean velocity in the layers, but frequent reference both to experimental results and to the known properties of turbulent motion has produced an analysis free from the common defects of such an approach. The paper does not lend itself to concise summary, but mention should be made of the following features: (1) A clear account of the properties of constant pressure layers both on smooth and rough surfaces; (2) a novel and informative approach to boundary layers by considering them as a "black box" which can be studied by observing responses to applied inputs; (3) the description of the velocity distribution in the outer part of boundary layers by assuming a constant eddy viscosity; (4) a correlation of the properties of equilibrium layers in adverse pressure gradients.

This paper will repay reading (and rereading) by everyone interested in this field, both for the general insight into the problem and because the reviewer believes that it marks a considerable advance towards a rational theory of turbulent boundary layers.

A. A. Townsend, England

3703. Nothwang, G. J., An evaluation of four experimental methods for measuring mean properties of a supersonic turbulent boundary layer, *NACA TN* 3721, 34 pp., June 1956.

A pitot tube, an x-ray densitometer, a hot-wire and a cold-wire probe were compared by obtaining pressure, temperature, mass flow, and density traverses in a turbulent boundary layer on a flat plate in a Mach 3.03 air stream. The boundary-layer thickness was about 0.2 in. and the Reynolds number 210,000. The traverses of mean pitot pressure, mean density, and mean total temperature obtained, respectively, by the pitot tube, x-ray densitometer, and cold-wire probe were consistent among themselves. However, the hot-wire measurements showed systematic deviations from the other probes; this result was also obtained in independent measurements at the Ames NACA laboratory.

A. M. Kuethe, USA

3704. Chuan, R. L., An investigation of shock wave-boundary layer interaction, Univ. So. Calif. Engng. Center, (OSR-TN-55-299), USCEC Rep. 40–201, 46 pp., Aug. 1955.

3705. Knauss, J. A., An estimate of the effect of turbulence in the ocean on the propagation of sound, *J. acoust. Soc. Amer.* **28,** 3, 443–446, May 1956.

Similarity theory is assumed valid for oceanic turbulence and, since scale of turbulence important in underwater sound propagation probably falls within inertial subrange, the intensity can be predicted knowing only ε, the rate of energy dissipation per unit mass. The value of ε is estimated from various sources of kinetic energy: wind-driven currents, waves, tides, convection. Although the first three can probably be estimated to within a factor of 5, it may not be possible to estimate the last to within an order of magnitude. Using the largest reasonable values for each of these terms, author concludes that turbulence is much less important to underwater sound transmission than are inhomogeneities in temperature. G. Power, England

3706. Owen, P. R., and Klanfer, L., On the laminar boundary layer separation from the leading edge of a thin aerofoil, *Aero. Res. Counc. Lond. curr. Pap.* 220, 14 pp. + 5 figs., 1955.

Low-speed wind-tunnel tests have shown that when a laminar boundary layer separates from the leading edge of a thin airfoil at incidence, the flow often becomes attached to the surface again some distance downstream. The region of separated flow is called a bubble and its chordwise dimension may vary from a minute fraction of the chord to a length comparable with the chord, depending on incidence, Reynolds number, and type of airfoil section. In this respect, a marked contrast between the lengths of bubble on the NACA 63-009 and 64-006 sections was found in tests at Langley Field.

It is suggested that the length of bubble (more accurately, its order of magnitude compared with the thickness of the laminar boundary layer at separation) depends primarily on the Reynolds number $(R^*_\delta)_s$ based on the displacement thickness at the separation point; if $(R^*_\delta)_s$ exceeds 400–500, the bubble is short; if less than this band of values, the bubble may be long. $(R^*_\delta)_s$ in turn depends on the distance of the velocity peak on the upper surface of the airfoil from the front stagnation point, and it is inferred that, at a given Reynolds number based on the chord, a long bubble is more likely to occur when the velocity peak is close to the stagnation point; but a scale effect, such as to cause the bubble to change from long to short as the Reynolds number is increased beyond a critical value, can also be expected.

These observations are used to comment on certain peculiarities in the stalling behavior of thin sweptback wings.

From authors' summary

3707. Head, M. R., The boundary layer with distributed suction, *Aero. Res. Counc. Lond. Rep. Mem.* 2783, 100 pp., 1955.

Experiments performed in flight at Reynolds numbers in the region of 3×10^6 have clearly demonstrated the stabilizing effect of small amounts of distributed suction on the laminar boundary layer. In the absence of a pressure gradient and in adverse gradients similar to those occurring on a normal airfoil, transition of the boundary layer to the turbulent form has been prevented by the use of such suction quantities as may be expected to lead to very considerable reductions in effective drag. It appears, however, that for extensive laminar flow to be achieved in this way, the surface must be free from such excrescences as would cause transition in the absence of suction. Laminar boundary-layer velocity profiles obtained with suction in the absence of a pressure gradient are found to be in good agreement with those calculated for the flat plate, and the suction quantities required to maintain laminar flow are similar to those suggested by stability theory.

From author's summary

3708. Hurley, D. G., and Thwaites, B., An experimental investigation of the boundary layer on a porous circular cylinder, *Aero. Res. Counc. Lond. Rep. Mem.* 2829, 14 pp., 1955.

Report describes an experimental investigation of the boundary layer on the surface of a porous circular cylinder at which there is a normal inward velocity. The primary object of the experiments was to test an approximate theory by B. Thwaites [*Aero. Res. Counc. Lond.* 11,830, Oct. 1948] for calculating the development of a laminar boundary layer under conditions of continuous suction. The formula given by Thwaites for calculating the momentum thickness of the layer gave results in accord with the experimental determinations. Owing to practical difficulties in the exploration of the very thin boundary layers and in the determination of the velocity gradient around the surface, other comparisons with the theory (such as the progressive development of the boundary-layer velocity distribution and of the prediction of the separation point) were difficult. Nevertheless, reasonable agreement between the theoretical and experimental velocity distributions was obtained, particularly for the lower wind speed of the experiment, but no adequate test of the prediction of the separation point was found possible. From authors' summary

Aerodynamics of Flight; Wind Forces

(See also Revs. 3673, 3678, 3682, 3685, 3691, 3706, 3719, 3729, 3734, 3735, 3743, 3766, 3774, 3791)

3709. Skinner, G. T., Time correlator for problems in aerodynamics, *NACA TN* 3682, 32 pp., June 1956.

An instrument for measuring time correlation functions of two stationary random electrical signals is discussed. Although primarily concerned with aerodynamically produced acoustic fields, this instrument may be suitable for other problems concerning turbulent field. In its operation, it makes use of such statistical methods as autocorrelation techniques.

Some experimentally determined functions are obtained and compared with theoretical values. The instrument is flexible so that the rate of sampling can be increased to handle high frequencies. The instrument was tested on sine waves, square waves, and turbulence behind a grid. J. H. Davidson, USA

3710. Spreiter, J. R., and Sacks, A. H., A theoretical study of the aerodynamics of slender cruciform-wing arrangements and their wakes, *NACA TN* 3528, 67 pp., Mar. 1956.

Formulas are given for the loadings and forces on cruciform wings with maximum span trailing edges and for tail lifts. Computations are carried out for the symmetrical 45° bank case for which the numerical method used was most feasible. Favorable comparisons are made between a 40- and a 4-vortex system relative to the positions of the centroids of vorticity. It is found that the roll-up of the vortex sheets takes a much larger distance than that estimated by Kaden, for the plain wing. Also that the "leap frog" distance (position where upper panel vortexes pass between lower panel vortexes) is small enough to be satisfactorily estimated by the simpler vortex structure not containing accurate detail roll-up characteristics. The latter is confirmed by water-tank experiments made by plunging models into the tank and photographically recording the surface behavior of the vortex system as the model progressed down the tank. Detailed plots of the progress of the wake patterns are presented, as are also illustrative records of the water experiments.

M. G. Scherberg, USA

3711. Rao, B. S. M., Virial problems related to simple wing profiles, *Proc. Indian Acad. Sci.* (A) **43,** 2, 53-66, Feb. 1956.

Starting from Blasius equation $-\frac{\rho}{2}\oint \omega'^2 z dz = M + iN$, author defines the virial N and the Hamilton Center ($M = 0$, $N = 0$). Using the notation of Milne Thomson ["Theoretical Aerodynamics," Macmillan, 1952, chap. 7], it is shown that there is a point (virial focus) where $N = N_0$, independent of incidence (*cf.* the focus or aerodynamic center.) The envelope of the lines $N_0 = 0$ forms the virial parabola (*cf.* the metacentric parabola). Several theorems are derived relating to the geometry of the virial parabola, the Hamilton Center, and the axes of the profile. These are applied to particular profiles such as Joukowsky, Karman-Trefftz, and von Mises profiles. A. W. Babister, Scotland

3712. Eminton, E., and Lord, W. T., Note on the numerical evaluation of the wave drag of smooth slender bodies using optimum area distributions for minimum wave drag, *J. roy. aero. Soc.* 60, 541, 61-63 (Technical Notes), Jan. 1956.

A slight modification of the authors' previous method [AMR **8,** Rev. 708] for the numerical evaluation of the wave drag of smooth slender bodies is presented. A numerical example is given for the cross-sectional area distribution of recent high-speed aircraft and it is shown that the present method with nineteen-point approximation for the sectional area curve gives drag within 2% of the analytical value. S. D. Nigam, India

3713. Garner, H. C., Simple evaluation of the theoretical lift slope and aerodynamic centre of symmetrical aerofoils, *Aero. Res. Counc. Lond. Rep. Mem.* 2847, 20 pp., 1955.

Author gives a rapid method of estimating theoretical lift slope (to 1/2%) and aerodynamic center (to 0.001 chord) for symmetrical airfoils in two-dimensional, incompressible potential flow. Method requires airfoil section coordinates and is based on Theodorsen's theory, certain approximations being made.

W. G. Cornell, USA

3714. Garner, H. C., and Batson, A. S., Measurement of lift, pitching moment and hinge moment on a two-dimensional cambered aerofoil to assist the estimation of camber derivatives, *Aero. Res. Counc. Lond. Rep. Mem.* 2946, 16 pp. + 11 tables + 18 figs., 1955.

Measurements were made in incompressible flow on a 4% cambered RAE102 airfoil, with control surfaces of 0.2 and 0.4 chord ratio, to determine camber derivatives. The effect of boundary-layer transition is investigated on upper and lower surfaces. Aerodynamic coefficients from balance measurements and from pressure data are compared and corrections for blockage and wind-tunnel interference applied. In general, linear variation of lift, pitch, and hinge-moment coefficients is obtained with control setting and with position of transition. Agreement of the results with theoretical work is explored and the conclusion reached that the lift and pitch camber derivatives are best estimated from the ratio of experimental to theoretical values of the lift curve slope. The hinge-moment camber derivative is, similarly, best estimated from hinge-moment curve slope. H. M. Spivack, USA

3715. Truckenbrodt, E., and Gronau, K. H., Theoretical and experimental investigations on delta wings with flaps, Inst. für Stromungsmechanik, Technische Hochschule Braunschweig, Rep. 55/12a, 45 pp., June 1955.

For a series of five delta wings of aspect ratios between 0.8 and 3.9, theoretical calculations of lift distribution have been carried out for various flap arrangements and flap deflections in incompressible flow, according to the lifting surface theory due to E. Truckenbrodt. For two of these wings, of aspect ratio 1.6 and 3.9, extensive wind-tunnel measurements have also been done. Good agreement was found between these measurements and the theoretical results. From authors' summary

3716. Abzug, M. J., Estimation of the lift and moment parameters of leading-edge flaps, *J. aero. Sci.* **22,** 9, 655-656 (Readers' Forum), Sept. 1955.

3717. Oakes, W. J., Jr., and Holliday, P. T., Analysis of a rolling pull-out maneuver, *J. aero. Sci.* **23,** 6, 517-529, June 1956.

Four methods for determining maximum first peak vertical tail load are examined. These are the familiar Kelley method, an approximation that side-slip angle equals angle of attack, solution of the nonlinear equations with angle of attack assumed constant, and solution of linearized equations. Comparisons are made for straight-, swept-, and delta-wing aircraft. Solution of nonlinear equations is shown to be the only consistent method among those examined. Linearized method is unable to predict proper damping in oscillatory mode. In transonic speed range, stable oscillations predicted by linearized method are shown to be unstable by nonlinear method. G. Isakson, USA

3718. Moore, B. C., Frequency response improves in-flight stability, *Control Engng.* **3,** 8, 85-93, Aug. 1956.

This case history of an autopilot development using frequency-response techniques shows how these techniques pinpointed sources of instability within the control system and how they explained the wide variance between simulated and actual aerodynamic motions. The strategy used by the author in circumventing the instability of his airborne "process" applies equally well

to any automatically controlled industrial process. He analyzes theoretical operation of the controlled system for likely causes of trouble, and then installs instrumentation to measure the actual behavior. Results: fast location of trouble and immediate redesign of the control equipment. From author's summary

3719. O'Bryan, T. C., Danforth, E. C. B., and Johnston, J. F., Error in airspeed measurement due to the static-pressure field ahead of an airplane at transonic speeds, *NACA Rep.* 1239, 13 pp., 1955.

Error in measurements of static pressure ahead of sharp-nosed bodies, at an inlet, and at the tip of a swept wing for $M = 0.7$ to 1.1 have been found in dive tests from models on "NACA transonic bump." Authors discuss mechanics causing errors and make some comparisons with linearized theory. They conclude with suggestions on optimum location for static pressure orifices.

W. Griffith, USA

3720. Neumark, S., and Thorpe, A. W., Theoretical requirements of tunnel experiments for determining stability derivatives in oscillatory longitudinal disturbances, *Aero. Res. Counc. Lond. Rep. Mem.* 2903, 14 pp., 1955.

The need of using stability derivatives of unsteady (oscillatory) motion is explained, and requirements of tunnel experiments for determining them are established. These are based on simple theoretical considerations, valid for both incompressible and compressible (sub- and supersonic) flow. Two alternative schemes of experimental tests are critically examined.

Nondimensional derivatives are defined and applied in modified stability equations, referred to fixed or moving systems of coordinate axes.

From authors' summary by M. Shinbrot, USA

3721. Wolhart, W. D., and Thomas, D. F., Jr., Static longitudinal and lateral stability characteristics at low speed of unswept-midwing models having wings with an aspect ratio of 2, 4, or 6, *NACA TN* 3649, 15 pp. + 2 tables + 24 figs., May 1956.

A systematic investigation was made in the Langley stability tunnel to determine the effects of the various components and combinations of components on the static longitudinal and lateral stability characteristics at low speed of unswept-midwing models having wings with an aspect ratio of 2, 4, or 6 through an angle-of-attack range from -4° to 32°. Also included are the effects of large angles of sideslip at several angles of attack for some of the components and combinations of components.

The results of this investigation have indicated that, at low and moderate angles of attack, decreasing wing aspect ratio decreases the tail contribution to longitudinal stability. Near the angle of maximum lift for the wing-alone configuration, there is a pronounced increase in longitudinal stability for all configurations involving the wing for all wing aspect ratios.

For the complete model, changes in wing aspect ratio generally had little effect on the tail contribution to directional stability throughout the angle-of-attack range investigated. The most noticeable effect of wing aspect ratio on the lateral stability characteristics occurred for configurations involving the aspect-ratio-2 wing-fuselage combination. These configurations showed abrupt variations in the side-slip derivatives or hysteresis occurring at small angles of sideslip for angles of attack of about 20° and 26°, respectively.

A large decrease exists in the vertical-horizontal tail contribution to directional stability at moderate and high angles of attack because of wing-fuselage interference at the tail which is counteracted by a stable shift in the directional stability of all wing-fuselage combinations. This combination of effects results in all complete-model configurations being directionally stable throughout the angle-of-attack range investigated.

From authors' summary

3722. Wright, K. C., Measurements of two-dimensional derivatives on a wing-aileron-tab system with a 1541 section aerofoil. Part I. Direct aileron derivatives, *Aero. Res. Counc. Lond. Rep. Mem.* 2934, 18 pp., 1955.

Measurements have been made of the direct two-dimensional damping and stiffness derivatives for a 20% aileron on an airfoil with a 1541 section in incompressible flow.

Corrections arising from the apparatus are discussed and reference is made to an attempt to measure the direct tab derivatives. The effects are shown of frequency parameter, amplitude of oscillation, Reynolds number, aileron angle, and position of transition on the wing.

Variation with frequency parameter is substantially the same as for vortex-sheet theory, and variation of amplitude produces little change in both derivatives. At the lowest Reynolds number there is little change in both derivatives with variation of aileron angle $\bar{\beta}$ for the condition of natural transition, but at higher Reynolds numbers the stiffness derivatives increase at $\bar{\beta} = -8$ deg. A forward movement of transition reduces the stiffness derivatives at the smaller aileron angles, but at $\bar{\beta} = -8$ deg, at the lowest Reynolds number, an increase results. Similar trends are observed for the damping derivatives above $\omega = 1$.

Comparison with vortex-sheet theory shows that the measured values of the stiffness $(-h_\beta)$ and damping $(-h_{\dot{\beta}})$ derivatives are approximately 0.6 of the theoretical values.

From author's summary

3723. Küchemann, D., and Redshaw, S. C., Some problems in aerodynamics and their solution by electrical analogy, *J. roy. aero. Soc.* **60,** 543, 191–197, Mar. 1956.

Some purely aerodynamical phenomena, which might profitably be investigated by means of electrical analog computers, are described. No attempt has been made to furnish a complete catalog of problems but rather to present current issues, the solution of which would aid the development of practical aerodynamics.

Consideration has only been given to those questions which can be solved more suitably by an analog computer than by a digital machine, although the feasibility of partially solving certain of them by the use of an analog computer, and completing the work with a digital machine, is mentioned.

In scope, the survey includes two- and three-dimensional airfoils as well as interference and a number of special problems.

The relative merits of the various forms of analog computers are not extensively discussed. From authors' summary

3724. DeYoung, J., and Barling, W. H., Jr., Prediction of downwash behind swept-wing airplanes at subsonic speed, *NACA TN* 3346, 104 pp., Jan. 1955.

A rapid method for estimating the downwash behind swept-wing airplanes is presented. The basic assumption is that of a flat horizontal sheet of vortexes trailing behind the wing. The integrations for the downwash are handled in a manner similar to both Multhopp's and Weissinger's approximate integrations in their span-loading calculations. The principal effects of rolling-up of the wake are treated as corrections to the flat-sheet wake. A simple approximate correction for the effect of the fuselage is applied. The agreement with available experimental data taken behind airplane models is good. Computing forms are included together with charts of pertinent functions, so as to enable simple direct application. From authors' summary

3725. Maskell, E. C., Pressure distributions illustrating flow reattachment behind a forward mounted flap, *Aero. Res. Counc. Lond. curr. Pap.* 211, 9 pp. + 13 figs., 1955.

A series of pressure distributions over a NACA 0015 wing with a forward-mounted chord split flap are presented.

Two basic types of pressure distribution are identified; and these are associated with fully detached flow behind the flap, and

with reattachment of the flow to the wing surface. An intermediate type—corresponding, it is suggested, to reattachment in the neighborhood of the wing trailing edge—is also identified.

The physical nature of the flow behind a flap is considered, and some ideas on the mechanism of reattachment are suggested.

From author's summary

3726. **Kell, C., Flight tests at transonic speeds on freely falling models,** *Aero. Res. Counc. Lond. Rep. Mem.* 2902, 32 pp., 1955.

In the past decade, the problems associated with high-speed flight have increasingly occupied the minds of many workers in aerodynamics and aircraft structures. The possibility of achieving supersonic flight has introduced a number of new problems not the least of which has been that of obtaining aerodynamic information throughout the transonic range of speeds. This report deals with one of the early test techniques developed for this purpose.

Basic bodies carrying the airfoils to be tested were released from an aircraft flying at height, and accelerated under the influence of gravity through the transonic speed range. Radar recorded the flight path and telemetering equipment carried within the body transmitted information to a ground station during the free fall.

The work on this method of test, which was started in 1943, was brought to a close in 1949. The main reason for abandoning the experiments was the limiting accuracy of the telemetering equipment, although other contributing causes were present.

Part I of this report is a historical precis of the work and part II a description of the models and the technique itself. In part III the drag measurements on nine wings are presented and in part IV the application of the technique to flutter tests is considered. Part V discusses the accuracy of the technique.

From author's summary

3727. **Lazzarino, L., Flight tests** (in Italian), *Aerotecnica* **35,** 2, 61–79, Apr. 1955.

Only flight tests concerning prototype aircraft are considered.

The first part of the flight tests performed with a prototype aircraft must reveal eventual unsatisfactory behavior of the aircraft in some particular flight conditions; the most probable causes of unsatisfactory behavior in flight are briefly reviewed, with consideration of suitable and possibly safe flight test procedure and apparatus for detecting them. Some interesting information regarding each cause is collected and critically discussed.

The second part of the flight tests performed with a prototype aircraft must demonstrate the compliance with general or particular requirements and furnish adequate data for the comparison of the aircraft with other similar ones and for the operational calculations; therefore, in this part of flight tests, high precision measurement must be performed in flight. The data, so obtained, must be reduced to standard air conditions; the errors, that can be introduced both in performing measurements in flight and in reducing them, are analyzed.

A considerable reduction in time and money, necessary for the second part of flight tests, can be obtained by limiting the measurements in flight only to the determination of the basic aerodynamic and engine data, from which the information necessary to comparisons or operational problems can be deduced through calculations. The actual engine data must be measured in flight in various typical atmospheric conditions, because their determination, starting from data measured in a particular atmospheric condition considerably different from that of operational interest, can be considered uncertain and practically inadequate.

From author's summary

3728. **Crocco, G. A., The future of high-speed flight** (in Italian), *Aerotecnica* **35,** 2, 59–61, Apr. 1955.

In the author's opinion, the future of high-speed aviation will consist in the use of manned astronautical missiles that will go out from the atmosphere and come back into it, utilizing the aerodynamic braking at the return to the earth.

From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 3691)

3729. **Miles, J. W., Unsteady supersonic flow,** Hdqtrs. Air Res. Devel. Command, U. S. Air Force, Baltimore, Md., Contract AF 18 (600)-432, xii + 569 pp., Mar. 1955.

During the past few years, the literature on approximate methods in the theory of perfect fluid flow has been enriched with a series of papers on the linearized theory of unsteady high-speed flow by the author, and this monograph on unsteady supersonic (and subsonic) flow is a further welcome addition which summarizes his own work and most of that of other workers in the subject. The linearized theory of unsteady gas flows caused by small motions of bodies in an otherwise uniform stream, with which this monograph is mainly concerned (there are chapters on accelerated flight and nonlinear problems at the end), is basically similar to the linearized theory for steady flows, but is generally much more difficult owing to the greatly increased complexity of the analysis caused by the extra independent variable. Advances in applications have usually been dependent on the use of transformations of the equations of motion which reduce this complexity, and the present author has contributed much to this aspect of the theory. The amount of material available for such a monograph as this is very great, and it is to the author's credit that he has managed to condense most of it into a comparatively short book without giving the reader any sense of strain.

The scope of the monograph is best indicated by giving a brief list of its contents. The first chapter deals with the basic assumptions and the conditions under which linearization is possible. Chapters 2 and 3 contain an account of various coordinate and other transformations, and chaps. 4 and 5 are concerned with the solution of the potential equation by separation of variables and reduction to the equation for steady flow. The succeeding chapters apply these ideas and methods to wings with 'simple' planforms (chap. 6), rectangular wings (chap. 7), quadrilateral wings (chap. 8), slender wings (chap. 9), delta wings (chap. 10), low-aspect-ratio rectangular wings (chap. 11), and slender nonplanar bodies (chap. 12). Chapter 13 is devoted to a discussion of accelerated flight, and an introduction to some nonlinear problems is given in chap. 14. An appendix deals with reverse-flow theorems, and there is an index of notation, an index of journals and other sources, and an author index. Very full references are given as footnotes throughout the work.

The monograph is mimeographed, and is published by the U. S. Air Force, under whose auspices it was prepared. It is to be hoped that all those who are interested in the subject and in the mathematical techniques will be able to obtain copies easily, because this invaluable monograph is unique in its field at present.

G. N. Ward, England

3730. **Pines, S., Iteration in semidefinite eigenvalue problems,** *J. aero. Sci.* **23,** 4, 380–381 (Readers' Forum), Apr. 1956.

This note presents an additional method to the set outlined in AMR **9,** Rev. 2311 for the problem of obtaining the eigenvectors and characteristic frequencies of a system of equations involving both elastic and rigid-body modes. G. C. K. Yeh, USA

3731. **Mazet, R., Some aspects of vibration tests on the ground and in flight** (in French), *ONERA NT* 34, 15 pp. + 8 figs., 1956.

Experimental determination of the generalized mass for each normal mode of vibration is accomplished by determining the small

changes in resonance frequencies due to the addition of known small masses to the airplane. The resonance frequencies and the logarithmic decrement of each mode of the airplane is determined in flight through an analysis of a record of the airplane's vibration response after setting off a charge of explosives placed on a lifting surface. References are given to original *ONERA* papers in which these methods were developed. The methods presented in this brief paper are most beautiful and are of great importance.

Y. C. Fung, USA

3732. Craven, A. H., and Davidson, I., The flexure-torsion flutter of cambered aerofoils in cascade, *Coll. Aero. Cranfield Rep.* 95, 19 pp. + 27 figs., Dec. 1955.

The work of Lilley [*AMR* **5,** Rev. 3200] has been continued by investigating experimentally the influence of camber on the behavior of fluttering airfoils in a cascade. Two sets of airfoils were used, having circular arc camber lines of 30° and 45°, respectively. Gap-chord ratio and stagger angle were varied over a wide range. Reynolds number was about 10^5.

The effect of camber is to increase the flutter speed and to decrease the flutter frequency.

Film records show that adjacent airfoils flutter nearly in antiphase. Flow visualization with a smoke filament indicates the occurrence of rather large separation regions during part of one cycle. Therefore reviewer regrets that the effect of Reynolds number has not been investigated. H. Bergh, Holland

3733. Chinneck, A., Holder, D. W., and Berry, C. J., Observations of the flow round a two-dimensional aerofoil oscillating in a high-speed air stream, *Aero. Res. Counc. Lond. Rep. Mem.* 2931, 18 pp., 1955.

Some interesting direct-shadow photographs of the flow patterns round a 10% thick airfoil oscillating in a pitching motion are presented. These show clearly the transonic shock-wave pattern associated with an airfoil in this type of motion.

The phase lag of the flow pattern is determined from the photographs from the position of the boundary-layer transition regions — a method which the authors claim is justified because a number of cases "showed that the phase lag in the movement of the transition regions was of the same order as that in the separation points and in the shock-wave pattern" (but the evidence on this point is not given).

The phase lag is calculated for a variety of Mach numbers, oscillation amplitudes, and frequency parameters, and the results are found to be in reasonable agreement with a semi-empirical theory due to W. P. Jones [title source, *Rep. Mem.* 2943, Dec. 1953].

L. C. Woods, Australia

3734. Houbolt, J. C., and Kordes, E. E., Structural response to discrete and continuous gusts of an airplane having wing-bending flexibility and a correlation of calculated and flight results, *NACA Rep.* 1181, 22 pp., 1954.

An analysis is made of the structural response of a wing to discrete gusts, to continuous sinusoidal gusts, and to continuous random atmospheric turbulence. The wing is flexible in bending and is free to move vertically. All gusts are two-dimensional and the analysis applies specifically to incompressible flow, though the lift curve slope may be chosen to include over-all corrections for aspect ratio and compressibility corrections. A numerical solution of the response equations is developed for the discrete gust; an exact solution is given for the sinusoidal gust; and the procedure is outlined for treating random atmospheric turbulence.

Comparison with flight tests indicates qualitative agreement on the effects of flexibility using the discrete gust analysis. Satisfactory quantitative agreement is obtained by means of the continuous turbulence analysis. These show peaks in the response corresponding to the free-body and fundamental wing-bending modes.

A. M. Kuethe, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3666, 3667, 3689, 3759, 3785)

3735. Rabbott, J. P., Jr., Static-thrust measurements of the aerodynamic loading on a helicopter rotor blade, *NACA TN* 3688, 9 pp. + 9 figs., July 1956.

An experimental investigation of the aerodynamic loading on a 15-ft-diam helicopter rotor blade in static thrust was conducted for a tip-speed range of 400 to 500 fps and disk loads of zero to about 2.5 lbs/sq ft. The chordwise pressure distributions at five spanwise stations are presented and a comparison is made between the measured spanwise loading and a simple theoretical loading modified by an approximate correction for a finite number of blades.

The variation of spanwise load distribution near the blade tip with thrust indicates that the blade-tip loss is proportional to the thrust coefficient. From author's summary

3736. Lausetti, A., Experimental determination of the aerodynamic characteristics of a Goldstein propeller as a lifting means (in Italian), *Aerotecnica* **36,** 1, 37-42, Feb. 1956.

Author describes a first series of experiments on a Goldstein propeller acting as a lifting means. These experiments were primarily intended to develop experimental methods for controlling the results of the theoretical calculations of the helicopter rotor characteristics. From author's summary

3737. Sheets, H. E., The slotted blade axial-flow blower, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-156, 11 pp. + 1 table + 18 figs.

The slotted blade applies boundary-layer control to the blades of axial-flow blowers. This offers a means to design axial-flow blowers for higher efficiencies or higher pressure coefficient, or possibly a combination of both. Test data of an experimental blower are presented, indicating blower efficiencies to 94% and stage efficiencies to 96% with high-pressure coefficient corresponding to a maximum flow deflection of about 52°.

From author's summary

3738. Pearson, C. E., Surge behavior in a three-stage compressor, *J. aero. Sci.* **22,** 11, 799-802, Nov. 1955.

Experimental pressure and flow patterns corresponding to the onset of surge in a three-stage compressor have been studied under a variety of operating conditions. Two very different types of surging, mild and deep, were encountered. The former always occurred in the presence of stall propagation and at an operating point which depended on the exit-chamber volume; its wave form was sinusoidal and its amplitude ranged from zero upwards. The latter was of large amplitude, had a distorted wave form, and corresponded to complete flow blockage which was not overcome until the exit pressure had dropped to almost the inlet value. The onset of this deep surge was not affected by the exit volume, although its subsequent character was. From author's summary

3739. Valdenazzi, G. L., The calculation of vaneless diffusers of centrifugal turboblowers (in Italian), *Aerotecnica* **35,** 2, 79-86, Apr. 1955.

A method of calculation is presented which describes the phenomena of motion in radial smooth conductors of turbomachines with particular reference to the vaneless diffusor of a centrifugal turbocompressor. It is postulated that a uniformity of conditions exists normal and in circumferential direction to the sides of the conductors, for which the problem becomes unidimensional, and hence the equations of motion become solvable.

The compressibility of the fluid and the loss at the exit are taken into account, which makes it necessary to know the experimental parameters. The method is applied to a numerical example in which, having fixed the initial conditions of a vaneless diffusor

of a centrifugal turbocompressor, one gets final values (velocity, angle of exit, pressure, and temperature) at the exit as well as the efficiency of the diffusor. L. M. Tichvinsky, USA

3740. Ury, J. F., The performance of reciprocating air-compressors, *Bull. Res. Counc. Israel* **50,** 1, 63-89, Dec. 1955.

In this paper empirical formulas are derived which permit a precalculation, with a fair degree of accuracy, of the performance of given compressor stages under varying working conditions. This is done by studying the deviations from an ideal polytropic process which occur in actual compressor stages. However, a lower limit of the pressure difference per stage is found below which this method, based on thermodynamic considerations alone, is not applicable. From author's summary

3741. Willens, D., Relative size of turbojet engine components, *J. aero. Sci.* **22,** 9, 652–653 (Readers' Forum), Sept. 1955.

3742. Bruce, R. J. T., and Vrana, J. C., Progress in development of a rig for testing variable area exhaust nozzles for turbojet engines fitted with afterburners, *Nat. aero. Establ. Canad. LR* 135, 8 pp. + appendix + 14 figs., May 1955.

A test rig, consisting of a preheat combustion chamber and a Derwent N.A.E.-type afterburner, has been developed for testing variable area exhaust nozzles. Air is supplied by a centrifugal compressor set. The air mass flow available is about 50 lb/sec, and, in order to test at the correct pressure ratios, a nozzle that was designed for use on an engine having a larger mass flow, a water-cooled plug, has been used to reduce the nozzle exit area.

A test was conducted on a variable area nozzle that was designed in the Engineering Section of the N.A.E.

From authors' summary

3743. Rocchi, B., Features of constant-speed airscrews (in Italian), *Aerotecnica* **35,** 1, 22-25, Feb. 1955.

The operation of constant-speed airscrews is described, and their features of sensitiveness and stabilization are illustratel.

From author's summary

3744. Slisskiĭ, S. M., Actual head of a turbine, one of a set in a power plant (in Russian), *Gidrotekh. Stroit.* **24,** 7, 28-31, 1955.

Author deals with the terminology of static heads as specified in "Terminology of hydro-turbines", 1953.

The existing terminology is criticized with particular reference to ambiguity concerning conditions at discharge when subjected to ejecting action due to discharge configuration. Correlation between model and full-scale tests is briefly dealt with. Author concludes that existing terminology needs elaboration, with particular reference to static pressure and total pressure.

The practice of ascertaining the operating characteristics of turbines in relation to the total working pressure is considered inadequate, Attention is drawn to the necessity of considering the discharge configuration when designing and investigating the performance of turbines. J. L. Koffman, England

3745. Shidlovskiĭ, V. P., Gas and fluid ejector pump design (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 119-123, Oct. 1954.

In short mixing chambers (length < 10 to 15 diameters) the temperature of the ejected fluid can be supposed as constant along the whole length if the velocity of the ejecting gas is high. Momentum and energy relations and the equation of continuity yield an expression for the exit velocity which reaches its maximum value under certain critical conditions, as in the case of pure gas ejectors. Neglecting the ratio of the densities of gas and fluid against unity, many expressions for critical quantities assume a simple form. Two diagrams show the relation between the total pressure of the entering air and the total (stagnation) pressure of the leaving mixture under critical conditions for pressures of 10 and 50 atm (142 and 711 psi, respectively) of the entering petroleum. Exact calculations show that neglected terms give differences in the third or fourth figure only. Critical parameters of the mixture depend mainly on the state of gas at the exit end of the mixing chamber, and so the results can be applied approximatively also to the ejection of fine powder by gas. Author points out that, owing to some simplifying assumptions, the developed expressions should be taken as qualitative indications only, which should be verified by experiment. A. Kuhelj, Yugoslavia

3746. Mludek, H., Calculation of bending vibration of long pinned and free steam-turbine blades (in German), *Maschinenbau-Technik* **5,** 4, 201-206, Apr. 1956.

After introductory remarks concerning East German industrial situation, well-known fourth-order bending differential equation with either quadratic or cubic mass and stiffness distribution is set up, the coefficients being specified by edge and half-length values of blade. Two fixed fifth-degree polynomials are introduced as Ritz-Galerkin trial functions and the lowest mode determined in usual way. Increase of natural frequency due to centrifugal force [AMR **9,** Rev. 378] is not considered. G. Plato, USA

Flow and Flight Test Techniques

(See also Revs. 3599, 3637, 3639, 3641, 3643, 3648, 3679, 3714, 3719, 3733)

3747. Midwood, G. F., and Hayward, R. W., An automatic self-balancing capsule manometer, *Aero. Res. Counc. Lond. curr. Pap.* 231, 9 pp. + 21 figs., 1956.

This note contains a brief description of an automatic self-balancing capsule manometer which has been developed primarily for the measurement of pressures encountered in the operation of supersonic wind tunnels. A remote indicating system is employed which is suitable for use with digital recording and card-punching apparatus.

The instrument has been designed to cover a range of 0-2 atmospheres absolute and has been adjusted and calibrated to give an accuracy of 0.01-in. Hg over the range 0.5-in. Hg to 60-in. Hg absolute. From authors' summary

3748. Winternitz, F. A. L., Effects of vibration on pitot probe readings, Parts I, II *Engineer, Lond.* **201,** 5227, 273–275, Mar. 1956; **201,** 5228, 282–290, Apr. 1956.

Careful measurements in towing tank and water tunnel show that cylindrical total pressure probes cantilevered normal to flow direction (such as used in penstock flow surveys) develop large errors due to resonant vibration at Karmen vortex-street frequency. Author attributes error to secondary flow set up by the vibration; reviewer believes errors can be accounted for by potential flow velocities associated with the lateral vibration. Use of streamlined support strut gets rid of vibration and hence of erroneous pressure readings. A. E. Bryson, Jr., USA

3749. Harris, E. L., Investigation of the time response and outgassing effects of pressure probes in free molecule flow, *Inst. Aerophys. Univ. Toronto TN* 6, 14 pp. + 1 table + 12 figs., Oct. 1955.

Author studies time response and outgassing effects of pressure probes in free molecule flow. Following analysis of Schaaf and Cyr [*J. appl. Phys.* **20,** no. 9, Sept. 1949], expressions are found for time constant of a probe and pressure difference due to outgassing; experimental results check closely with theory. At pressures of a few microns there may be a measurable pressure difference between gage volume and system under steady-state con-

ditions, caused by emission of gas. This outgassing rate decreases asymptotically with time; tests were made during the latter period. M. Z. v. Krzywoblocki, USA

3750. Thomson, T. A., A multi-tube manometer for an intermittent supersonic wind-tunnel, *Aero. Res. Labs., Melbourne, Austral.* Instr. Note 56, 4 pp. + 3 figs., Oct. 1955.

Special features of a new manometer for the blow-down wind tunnel at the University of Sydney are described. Provision for holding manometer readings by use of valves in the liquid columns is made for convenience in recording and to protect the instrument from violent pressure changes at the beginning and end of a test run. These valves are formed from a V-shaped block of Teflon sliding in a stainless-steel mating surface in such a way that the passages containing the liquid may be connected or interrupted.
W. H. Phillips, USA

3751. Morris, D. E., and Winter, K. G., Requirements for uniformity of flow in supersonic wind tunnels, *Aero. Res. Counc. Lon. curr. Pap.* 197, 8 pp. + 1 fig., 1955.

An analysis is made of the effects of nonuniformity of flow on the pressure measurements on the surface of a model and also on the force and moment measurements, and the following standards of flow uniformity are derived: variations in flow direction to be less than $\pm 0.1^{\circ}$ in the range $M = 1.4$ to 3; variation in Mach number to be less than ± 0.003 at $M = 1.4$, increasing to ± 0.01 at $M = 3$.

A brief analysis is made of the errors in model manufacture and their effects on force and pressure measurements. Using the same standards as were used in deducing the requirements for flow uniformity quoted above, it is concluded that present standards of model manufacture are satisfactory over all, though for accurate pressure-plotting tests at low supersonic Mach numbers ($M \approx 1.4$) a higher standard is desirable. From authors' summary

3752. Bassière, M., Measurements and registration of strain gage results in wind-tunnel balances (in French), *ONERA NT* 32, 12 pp. + 12 figs. + 10 plates + 1 table, Jan. 1956.

System of wire strain gage for aerodynamic balance is discussed. An example of measurement utilizing continuous-current feed and inserting a special potentiometer to correct the output of thermocouples for the temperature compensation is described. The sensibility and stability of the recorder are assured with a stress of $80 g/mm^2$ and an accuracy of 2×10^{-3}. The measurement can be carried out with maximum sensibility throughout the whole range. The recorder allows card printing and punching of the measured data. From author's summary by M. Sanuki, Japan

3753. Monaghan, R. J., Tests of humidity effects on flow in a wind tunnel at Mach numbers between 2.46 and 4, *Aero. Res. Counc. Lond. curr. Pap.* 247, 18 pp. + 10 figs., 1956.

Static and pitot pressure distributions were measured in the working section of a 5 in. × 5 in. supersonic wind tunnel at nominal Mach numbers of 2.48, 3.25, and 4, over ranges of absolute humidity at the inlet from 5×10^{-5} to 3×10^{-3}. For these conditions, previous work would indicate that a condensation shock would occur in the nozzle.

For a stagnation pressure of 1 atm and stagnation temperatures giving zero heat-transfer conditions at the walls, no humidity effects were discernible if the absolute humidity was less than 2×10^{-4} at $M = 2.48$, 3×10^{-4} at $M = 3.12$, and about 5×10^{-4} at $M = 3.8$. Above these critical values there was a gradual deterioration in flow distribution, but no localized disturbances were found.

Tests at nominal $M = 3.25$ showed no effect of relative humidity if the absolute humidity was less than the critical values quoted above. (In a typical case of an absolute humidity of 2×10^{-4}, the relative humidity was varied between 6×10^{-3} and 5×10^{-2} without showing any effect.) From author's summary

3754. Le Grives, E., and Paulon, J., Optimal adaptation of supersonic ejectors (in French), *Rech. aéro.* no. 50, 27–30, 1956.

To assist ejector designers to determine the optimum secondary flow performance for specified primary flow conditions, authors present, in graphical form, theoretically determined curves using conventional ejector primary and secondary flow parameters. The calculations show these conditions are obtained when primary and secondary static pressures at entry to the mixing section are equal, and confirmatory experimental results are presented showing close agreement between theory and practice. However, authors state that optimum performance can only be achieved providing the correct values for mixing length, primary nozzle position, etc., are initially chosen. G. C. Quigg, Australia

Thermodynamics

(See also Revs. 3679, 3680, 3681, 3741, 3749, 3750, 3754, 3765, 3769, 3784, 3802)

3755. Siegel, A., Stochastic basis of Onsager's minimum principle, *Phys. Rev.* (2) **102,** 4, 953–959, May 1956.

Paper shows that the thermodynamic equations of motion follow from Onsager and Machlup's minimization condition, provided a "coarse" time scale is used. Fluctuations are critically discussed. D. ter Haar, England

3756. Kaplan, T. A., Relationship between the reciprocity theorems of Onsager and of Callen-Greene, *Phys. Rev.* (2) **102,** 6, 1447–1450, June 1956.

Onsager's reciprocity theorem is extended to linear non-Markoffian processes; the reciprocity relation due to Callen-Greene is also extended to include the imaginary (as well as the real) part of the admittance matrix. In terms of these extensions, the two theorems are shown to be completel equivalent.
From author's summary

3757. Kümmel, H., The Boltzmann equation and irreversible thermodynamics (in German), *Z. Phys.* **145,** 4, 496–503, 1956.

3758. Christianssen, T. G., Supplement to Mollier's diagram for air-vapor mixture (in Swedish), *Tekn. Tidskr.* **86,** 11, p. 235, Mar. 1956.

3759. Glansdorff, P., Jaumotte, A., and Baland, J., On the effective power of jet propulsion (in French), *Bull. Acad. roy. Belgique Cl. Sci.* (5) **41,** 9, 1029–1036, 1955.

Authors give a rational method, based on the laws of mechanics and thermodynamics, for the calculation of the effective power of jet propulsion. In addition, this method has the advantage of being general, since it applies to all possible cases of translatory motion of the apparatus (uniform and nonuniform, rectilinear and curvilinear) as well as to nonstationary states of the fluid. Details cannot be given in a short review.
E. Leimanis, Canada

3760. MacDonald, D. K. C., White, G. K., and Woods, S. B., Thermal and electrical conductivities of the alkali metals at low temperatures, *Proc. roy. Soc. Lond.* (A) **235,** 1202, 358–374, May 1956.

Measurements of the thermal and electrical conductivities of very pure lithium, sodium, potassium, rubidium, and caesium have been made down to temperatures as low as 2 K. The respective resistivities W and ρ may be written as the sum of an impurity resistance (W_0, ρ_0) and a so-called "ideal" component (W_i, ρ_i) due to scattering by the thermal vibrations of the lattice.

The terms in the thermal resistivity may be represented by

$$W_0 = A/T \quad \text{and} \quad W_i = BT^n \quad \text{for} \quad T \leqslant \theta/10$$

where $n \simeq 2$ and $A = (\rho_0/2{\cdot}45) \times 10^8$ cm deg^2 W^{-1}. Current theory predicts that the quantity $C \equiv B\theta^2/W_\infty N^{2/3}$ should be constant, where N is the number of free electrons per atom and W is the measured high-temperature resistivity. Taking $N = 1$, the present experiments yield $C \simeq 18 \pm 4$.

The electrical resistance may be written

$$\rho = \rho_0 + \beta T^m \quad \text{for} \quad T < \theta/10$$

with $m \simeq 5$ except for sodium, where, below 8 K, m is found to increase to 6. The theoretical relationships which exist between the low-temperature "ideal" resistivities and those at higher temperatures are discussed in conjunction with the measured values. It is concluded that, with the existing theories, no common adjustment of θ can give satisfactory agreement of theory with experiment.

A new simple semi-empirical expression is put forward for W_i which provides rather good agreement with experiment.

From authors' summary

3761. **Palit, S. R., Thermodynamic interpretation of the Eötvös constant,** *Nature* **177,** 4521, p. 1180, June 1956.

Heat and Mass Transfer

(See also Revs. 3503, 3545, 3638, 3648, 3662, 3679, 3690, 3700, 3755, 3760, 3799, 3801)

3762. **Otis, D. R., Solving the melting problem using the electric analogy to heat conduction,** 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prep. 3, 11 pp.

Consider a one-dimensional finite slab of solid material with arbitrary prescribed heat $q_a(t)$ taken out at the right end $x = a$, and with arbitrary heat $q_s(t)$ supplied at location $x = s(t)$, where $s(t)$ represents the location of the melting front, and $s(0) = 0$. (It is assumed that the melt which develops between $x = 0$ and $x = s$ is continuously spirited away, so that it no longer participates in heat transfer.) It was shown by H. G. Landau [AMR **4,** Rev. 430], for the slightly more special boundary condition $q_a(t) = 0$, that a coordinate transformation may be made to variables $\bar{x}, \bar{t}$ which establishes $\bar{x} = 0$ and $\bar{x} = 1$ as permanent boundaries, and the front propagation term now appears in the form of an (unknown) heat-generation term in the differential equation, and also as an (unknown) heat-supply term in the $\bar{x} = 0$ boundary condition. However, Landau found that, for digital programming, the transformed equation may offer some advantages over standard approaches.

Author now further exploits this idea, and sets up problem for analog computations. Electric circuit used is sketched, and some results are plotted. G. Horvay, USA

3763. **Kolodner, I. I., Free boundary problem for the heat equation with applications to problems of change of phase,** *Comm. pure appl. Math.* **9,** 1, 1-31, Feb. 1956.

A general method is presented for the reduction of one-dimensional free boundary problems for the heat equation to the solution of integro-differential equations for the function $R(t)$ describing the boundary motion. These equations are nonlinear, but of the Volterra type of the second kind and are, therefore, amenable to numerical treatment. The method requires the construction of an auxiliary functional which is a solution to the heat equation in an extended domain with jump conditions across the moving boundary. Uniqueness of this auxiliary function is proved under broad conditions and three different functional equations for $R(t)$ are derived. For the most convenient of these, it is only possible to prove that its solution is, in fact, the required function $R(t)$ for the class of problems in which $R(t) \leqslant 0$. The functional equation for several illustrative problems is obtained, including motion of a plane liquid-vapor interface, decay by evaporation of a liquid drop, and freezing of a lake of finite depth. J. H. Weiner, USA

3764. **Wright, P. J. F., and Gregory, J. M., An investigation into methods of carrying out accelerated freezing and thawing tests on concrete,** *Mag. Concr. Res.* **6,** 19, 39-47, Mar. 1955.

It was noted in earlier investigations that accelerated freezing and thawing tests on concrete carried out using a continuously refrigerated room produced results more rapidly than similar tests using a cabinet-type refrigerator, although in each case the specimens reached the same limiting temperatures of about 5 and 60 F. Attempts have therefore been made to modify the technique so that results can be obtained more rapidly in the refrigerator.

The tests show that damage occurs more rapidly when specimens are frozen immersed in water than when frozen in air, although the rate of freezing is lower. This suggests that evaporation of water from the surface of the specimens before freezing may mitigate the damage by reducing the stresses developed near the surface when the water freezes. Little was gained by the use of a brine bath surrounding the water-immersed specimens.

Measurements of the temperatures of the specimens during freezing and thawing suggest that two cycles per day could be carried out successfully in the refrigerator, in place of the one cycle per day formerly used. From authors' summary

3765. **Kurlato, A. V., Thermodynamics of silt transporters** (in Russian), *Gidrotekh. Stroit.* **22,** 10, 34-36, 1953.

The theoretical basis is discussed and equations developed for design of uninsulated silt transporters located in below-zero surrounding atmosphere. Such problems occur in dredging or similar operations in below-zero weather.

The solution is more difficult than that for pure liquid or gas lines, because varying heat content of different liquid-born solids must be accounted for. Author states that latent heat of freezing cannot be utilized because freezing occurs gradually rather than instantaneously. Heat generated by friction is small and can also be disregarded. The remaining factors which determine if freezing will occur are: initial heat content of the silt (all components included), velocity of silt, length of pipe, its diameter, outside temperature, and wind velocity. If heat content of silt going into the pipe per unit time is greater than that lost per unit time through pipe surface, freezing will not occur.

A time-saving graph is included, showing heat lost per 1 m^3 of silt: q_2 in calories/meter^3/hour per m^2 of uninsulated surface at various temperatures and wind velocities. Using the equations and the graph, and knowing length of pipe, initial temperature of silt, and nature of its components, the diameter of the pipe and velocity required to prevent freezing can readily be calculated.

B. Hawrylyshyn, Canada

3766. **Lees, L., Influence of the leading-edge shock wave on the laminar boundary layer at hypersonic speeds,** *J. aero. Sci.* **23,** 6, 594-600, 612, June 1956.

In the opinion of the reviewer, the essentials of this paper are well covered by the author's summary which follows:

In order to bring out the importance of the leading-edge region at hypersonic speeds, the influence of the leading-edge shock wave on the laminar boundary layer is investigated in two simple cases of steady flow over a semi-infinite, insulated flat plate: (1) sharp leading edge; (2) blunt leading edge, as approximated by a normal shock wave. The streamlines that enter the boundary layer over a large region of the plate surface have previously crossed the shock wave very near the leading edge, where the shock is strong and highly curved. Consequently, the temperature at the outer edge of the boundary layer is appreciably higher than free-

stream temperature, and the vorticity there is not zero. The effects of this shock-wave "heating" and vorticity on the boundary layer are shown to be much larger than the usual "errors" made in the boundary-layer theory, and an estimate of these effects can therefore be obtained within the framework of that theory. The numerical magnitude of the shock-wave influence is found to be appreciable. For the case of the blunt leading edge, the slope of the curve of induced pressures plotted against the hypersonic interaction parameter closely approaches the experimental data of Hammitt and Bogdonoff obtained in helium at large values of this parameter. These approximate results show that the influence of the leading-edge region at hypersonic speeds requires careful theoretical and experimental study.

From author's summary by A. J. Eggers, USA

3767. Yang, K.-T., and Sogin, H. H., A numerical method for laminar heat transfer on cylinders in plane compressible flow, *J. aero. Sci.* **23,** 3, 277-279 (Readers' Forum), Mar. 1956.

Author describes a numerical method free from assumptions concerning property values and based on Goertler's method of finite differences.

Finite differences are substituted for partial derivatives in dimensionless continuity, momentum, and energy equations. By starting the calculations near the stagnation point and using small intervals in the first steps, errors can be kept small.

R. K. Sherburne, USA

3768. Eckert, E. R. G., and Livingood, J. N. B., Calculations of laminar heat transfer around cylinders of arbitrary cross section and transpiration-cooled walls with application to turbine blade cooling, *NACA Rep.* 1220, 21 pp., 1955.

Purpose is to present an approximate method for the calculation of the local heat-transfer coefficient and surface temperature at any point on the surface for an arbitrary given distribution of coolant velocity along the surface; pressure gradients can be present. The distribution of coolant velocity along the surface necessary to give a predetermined distribution of heat-transfer coefficient and surface temperature can also be calculated. The assumptions are: that the flow is two-dimensional and steady; that the internal frictional heating in the boundary layer is negligible; that the density, viscosity, and heat conductivity are constant; and that the temperature gradients along the surface are negligible. With these assumptions, the boundary-layer equation of motion and the boundary-layer temperature equation are each integrated with respect to distance from the surface. Trigonometric expressions are then assumed for the velocity and temperature profiles through the boundary layer and these expressions are inserted into the integrated boundary-layer equations of motion and temperature. The two resulting ordinary differential equations can be integrated step-by-step along the surface with the aid of charts that greatly reduce the amount of computation that would otherwise be required.

The method is used to calculate the local heat-transfer coefficients and surface temperatures over the forward portion of two transpiration-cooled turbine blades for a constant coolant rate along the surface and also to calculate the coolant flow distribution necessary to keep the surface temperature uniform.

Reviewer believes that, along with the factors that are stated to influence transition from laminar to turbulent flow, mention should also be made of the coolant outflow velocity through the surface. An outflow through the surface may have a powerful transition-producing effect.

N. Tetervin, USA

3769. Hutchinson, F. W., LaTart, L. J., and Smith, N. W., A theoretical and experimental study of liquid-to-liquid heat transfer in hot water heaters, *Heat. Pip. Air Condit.* **27,** 2, 111-115, Feb. 1955.

Based on an experimental investigation of water-to-water heat transfer, it was found that the empirical equations commonly used for turbulent flow within a tube and for free convection outside the tube permit evaluation of film coefficients, hence of the over-all coefficient of heat transfer, which agrees—within the limits of experimental error—with the values obtained by test under conditions simulating those existing within a water heater. Further, the demonstrated major influence of the outside thermal resistance is such that a reasonably accurate approximate correlation can be obtained between water-to-water mean temperature difference and rate of heat transfer. The approximate correlation—accurate to within better than 10% for the greater part of its range—is valid over a temperature range from 86 F to 186 F, a velocity range from 3 to 6 gpm (in ½-in. or ⅝-in. nominal-diameter copper tube), and is applicable to various tube wall thicknesses.

Where accuracy greater than that of the correlation curve is required, the theoretical relationships can be applied; similarly, for ferrous pipe or alloy tubes, the theoretical relationships permit correction of the experimental data to obtain design values of the rate of heat transfer.

From authors' summary

3770. Miesse, C. C., The effect of a variable evaporation rate on the ballistics of droplets, Ann. Meet. Amer. Rock. Society, Cleveland, O., Sept. 19–21, 1955, Pap. 223-55, 14 pp. + 6 figs.

In order to allow for the effect of the variation of evaporation rate of a liquid droplet with its Reynolds number on its velocity and diameter variations, the present analysis considers the ballistics and evaporation (Froessling's) simultaneously. The resulting nonlinear equation yields analytical solutions for discrete values of the viscosity to still-air evaporation-rate parameter, which permit ready determination of the variation of drop size and relative velocity with time and distance. The results indicate that the constant-evaporation-rate analysis is valid for large values of the parameter mentioned above, but should be modified for smaller values. Numerous illustrative curves are presented, and the analysis is applied to available experimental data.

Conclusions: (1) The ballistics of a liquid droplet injected into a uniform air stream can be determined analytically for several values of the ballistics parameter, by simultaneous solution of the evaporation and ballistics equations; (2) the effect of the increase of evaporation rate due to relative velocity is that both the distance traveled and droplet lifetime are reduced; (3) relative velocity effects produce a considerable change in the drop-size curves.

K. J. De Juhasz, Germany

3771. Savic, P., Hydrodynamical and heat transfer problems of liquid spray droplets, *Nat. Res. Counc. Canad., Div. mech. Engng., Quart. Bull.* 5 pp. + 4 figs., Jan./Mar. 1953.

The dynamics of liquid droplets moving in a continuous medium was studied by means of high-speed photography in a vertical wind tunnel having a slowly diverging working section in which droplets could be kept suspended in a stable position over a period of several minutes. The shape of the drop oscillates about a symmetrical mean shape. As the droplet diameter increases, the underside of the drop flattens, then a dimple appears; finally, the drop becomes bag-shaped, breaks up, and rolls into smaller droplets. To a certain degree this phenomenon can be explained also theoretically, by equating the aerodynamic pressure to the gravity and capillary forces. It was also found that a lower air velocity is needed to break up the droplet in a suddenly applied air stream.

The circulation within the drop has an influence on the heat transfer. The circulation is greater when the drop is larger, and thus compensates to some extent for the lesser surface-to-volume ratio, as far as temperature rise, and therefore ignition delay, is concerned. This phenomenon was examined experimentally using liquid-in-liquid drops of large size, and taking pictures of the flow within the drop. However, it is admitted that circulation is probably absent in droplets of a size usual in fuel sprays, unless the

temperature is high enough to reduce the surface tension below a certain critical level.

Some interesting conjectures are advanced regarding combustion, the hydrodynamic repulsion of the droplets, demulsification of emulsions. It is also surmised that colloidal techniques may be utilized to aid in the control of combustion and evaporation of sprays, and in other process phenomena.

K. J. De Juhasz, Germany

3772. Batschelet, V. E., and Grün, F., Numerical solution of the diffusion equation with superimposed convection (in German), *ZAMP* **7**, 2, 113-120, 1956.

A procedure is presented for the solution of the boundary-value problem $u_{xx}\ (1/r)(ru_r)_r - [v(r)/D]u_x = 0$; $u(0,r) = u^*$; $u_r\ (x, R) = -ku(x, R)$, relating to the steady-state diffusion of dissolved material from a fluid flowing with a velocity distribution $v(r)$ through a cylindrical tube, the initial concentration u^* being fixed and a finite mass-transfer resistance occurring at the tube's surface. Rather than employ the familiar relaxation technique, authors reduce the linear differential equation to a pair of second-order linear difference equations, using the customary methods of approximating differentials with finite differences. The difference equations are solved by the standard analytical method, the constants being found numerically.

Reference should be made to papers by Van der Does De Bye and Schenk [AMR **6**, Rev. 548] and by Schenk and Dumone [AMR **7**, Rev. 4030], in which the same or related problems are discussed from the viewpoint of their analytical solutions.

R. L. Pigford, USA

3773. Pastonesi, G., and Colombo, G., Heat exchange in longitudinal finned pipes (in Italian), *Termotecnica* **10**, 4, 148-154, Apr. 1956.

3774. Welsh, J. P., Cooling procedures necessary to avionic reliability, *Aero. Engng. Rev.* **15**, 5, 110-113, May 1956.

3775. Carhart, N. A., The problem of cooling electronic equipment in high-performance aircraft, *Aero. Engng. Rev.* **15**, 5, 76-81, 109, May 1956.

3776. Threlkeld, J. L., and Jordan, R. C., Solar radiation during cloudless days, *Heat. Pip. Air Condit.* **27**, 2, 117-122, Feb. 1955.

Paper presents the results of research on the incidence of solar and sky radiation during cloudless days on horizontal, south-facing vertical and south-facing tilted surfaces. Calculated curves based upon an assumed standard summer atmosphere and an assumed standard winter atmosphere are presented. Comparisons of the calculated curves with recorded clear-day radiation measurements are made for Lincoln, Neb.; Madison, Wis.; Columbia, Mo.; Rapid City, S. D.; Nashville, Tenn.; and Blue Hill, Mass.

From authors' summary

Combustion

(See also Rev. 3742)

3777. Marble, F. E., Flame theory and combustion technology, *J. aero. Sci.* **23**, 5, 462-468, May 1956.

Paper describes some contributions of Dr. von Karman and collaborators and how they fit into present combustion theory. Aerothermodynamic and chemical fundamentals are outlined. Laminar flame propagation, two-dimensional combustion, and flame quenching near a cool surface are discussed. Paper forms part of a tribute to Dr. von Karman. R. A. Gross, USA

3778. Petrein, R. J., Longwell, J. P., and Weiss, M. A., Flame spreading from baffles, *Jet Propulsion* **26**, 2, 81-86, 97, Feb. 1956.

Experimental results are reported involving baffle geometry, size, and blockage; baffle spacing and duct size; pressure; equivalence ratio; approach velocity; tailpipe length; and turbulence effects of flame spreading in a practical range of interest.

An empirical correlation of data is presented based on the fact that these parameters change the rate of flame-spreading and translate the distance scale. The authors do not recommend extending the correlation to "other geometries or wider operating ranges".

Flame speeds and efficiencies in a hypothetical system of homogeneous local combustion were calculated and compared with experimental values. The lack of agreement is attributed to the actual nonhomogeneity of material at any point during an extended time (thus giving a time average efficiency much lower than predicted by assumption of local burning) and to the neglect of transfer normal to the flow direction. The comparison illustrates the author's comment that no theory exists which can "quantitatively predict the rates of flame-spreading in turbulent ducted flow".

The "optimum homogeneous burning" system discussed illustrates an extreme of mixedness. The probable system of burning consisting of detached masses of burned, partially burned, and unburned material introduces the idea of feedback mechanism causing the interdependence of burning rate and flow.

The comments and the interpretation of data presented by the authors emphasize the complexity of flame-spreading study and are worthy of comparative study. A. C. Tobey, USA

3779. Putnam, A. A., and Dennis, W. R., Survey of organ-pipe oscillations in combustion systems, *J. acoust. Soc. Amer.* **28**, 2, 246-259, Mar. 1956.

Survey summarizes relevant literature on singing flames, flames propagating in a tube, oscillating flames which may be considered related to Rijke gauze tones, and flames in combustion systems akin to industrial furnaces and ramjet and rocket burners.

Suggested explanations of self-excitation are surveyed and authors freely give their own views.

Reviewer believes that comparison of results from many different combustion systems (53 references), while not exhaustive, is helpful guide to need for further work.

J. Barr, Scotland

3780. Putnam, A. A., and Dennis, W. R., Organ-pipe oscillations in a burner with deep ports, *J. acoust. Soc. Amer.* **28**, 2, 260-269, Mar. 1956.

Data are presented on acoustic oscillations produced by a burner using a hexagonal bank of hypodermic tubes as deep ports. Most tests were made with ethane as fuel, but some tests used methane and propane for comparison. Diameter and length of combustion chamber were varied. It was found that combustion chamber could be considered as a driver which forced slugs of gas in ports to oscillate. Burning of incremental pulses of combustible mixture furnished energy to drive oscillations when pulses burned in phase with chamber pressure oscillation. Phasing depended on a time-lag factor which was a function of velocity of gases through a space, similar to dark space, between burner ports and mean burning points, and width of space itself. The oscillations not only ceased when there was failure to satisfy timing criterion, but also ceased upon approach to either rich or lean blowoff limits of conventional type. This premature cessation apparently results from the flame burning from fewer ports as the limits are approached, less driving energy being available.

From authors' summary by J. Barr, Scotland

3781. Kaskan, W. E., and Noreen, A. E., High-frequency oscillations of a flame held by a bluff body, *Trans. ASME* **77**, 6, 885-895, Aug. 1955.

Authors examine flame-driven acoustical vibrations in a 2- × 4-in. duct, with flame stabilization on a V-gutter. Pressure variations are measured with a microphone and flame is examined by high-speed and single-picture schlieren photography. The oscillation limits were also determined for natural gas, propane, ethylene, as a function of mixture velocity and fuel/air ratio.

It has been shown that the oscillations are characterized by the periodic formation of vortexes at the oscillation frequency. The frequency of the oscillations has been shown to correlate with the transverse mode where the pressures at the two flame holder tips are out of phase, with the vortexes formed alternately as in a von Karman vortex trial.

A theory is derived on the assumption that the oscillation is driven by vortex-induced flame distortion which shows that $S_u U^r = constant$, where S_u is the laminar flame speed and U the flow velocity. Experimental results are in general agreement with this and show that $r = 1.6$ approximately.

A. H. Howland, England

3782. Miesse, C. C., One-dimensional velocity variation of a burning droplet. 1953 Heat Transfer and Fluid Mechanics Institute, 223–240, 1953, Stanford, Cal.

The problem of determining the axial velocity variation of a burning droplet injected into a combustion chamber is solved analytically by making several assumptions regarding the burning rate of the droplet and the velocity variations of the surrounding gases. The solution, which depends upon the jet velocity, the final velocity of the gases, the length of the chamber, the viscosity of the gases, and the burning rate of the droplet, also gives the size of droplet which will be completely burned in a given distance, as well as the lifetime of the droplet. Since no data appear to be available on the burning rate of a droplet in a gas stream, a method for determining the burning rate is derived by assuming that Froessling's law, which has been confirmed experimentally for evaporation, can be applied to the similar process of combustion. Illustrations include several typical velocity variations, as well as a dimensionless graph from which the initial drop size can be determined for known properties of the system.

Conclusions: (1) By making several simplifying assumptions, it is possible to determine analytically the velocity profile of a burning droplet entrained in a gas stream; (2) for a given combustion chamber, the maximum diameter of a droplet which will be completely evaporated in a given distance downstream of the injector varies directly as the square root of its evaporation rate, and inversely (approximately) as the square root of its jet velocity; (3) even moderate relative velocities increase the effective evaporation rate, and also the maximum initial drop size, very considerably.

K. J. De Juhasz, Germany

3783. Korach, M., Theory of tunnel furnaces and speedy burning, *Magyar Energiagazdasag* **8,** 7, 246–254, July 1955.

3784. Zancani, C., On immersed combustion: proposal of a thermic cycle and its new application (in Italian), *Termotecnica* **9,** 2, 50–56, Feb. 1955.

3785. Bruce, J. T., and Vrana, J. C., Development of a test rig and 1000-hour test on blades of various alloys to determine the fouling and corrosive effects of the ash from the combustion of a Western Canadian residual fuel, *Nat. Res. Counc. Canad. mech. Engng.* Rep. MT-28, 15 pp. + 15 figs., September, 1955.

A test rig has been developed for studying the deposition on, and the corrosion of, gas-turbine blade materials caused by the ash in the exhaust from a residual-fuel-burning combustion chamber.

A 1000-hour test has been carried out in which blades of Vitallium, Inconel X, and Nimonic 80 were exposed to the combustion products of residual fuels from the Leduc Field in Alberta.

Only small amounts of deposition and corrosion were observed.

From authors' summary

Acoustics

(See also Revs. 3677, 3779, 3780)

3786. Rayleigh, J. W. S., The theory of sound, 2nd ed., New York, Dover Publications, 1956. Vol. I, xxxii + 480 pp.; Vol. II, xvi + 504 pp., $1.95 each. (paperbound)

3787. Ingard, U., and Pridmore-Brown, D. C., Scattering of sound by sound, *J. acoust. Soc. Amer.* **28,** 3, 367–369, May 1956.

Authors derive theory of interaction of high-intensity sound beams intersecting at right angles. When one beam has frequency 120 kcps and pressure level 130 dbp, level of sum and difference tones by interaction with 10 kcps cross beam is about 50 db below that of latter. Rough experiments indicate levels some 10 lower, but angles of maximum scattering occur at about proper values.

V. Salmon, USA

3788. Welkowitz, W., Directional circular arrays of point sources, *J. acoust. Soc. Amer.* **28,** 3, 362–366, May 1956.

Linear arrays of acoustic and electromagnetic point sources suffer from certain drawbacks: In a plane through the array they produce a bidirectional rather than a unidirectional pattern. Also, the main lobe width of the optimum pattern varies as the beam is rotated electrically. Circular point source arrays are free from these drawbacks. Author develops theory of circular arrays. The effect of diameter and number of sources is illustrated quantitatively.

M. C. Junger, USA

3789. Lyon, R. H., Response of strings to random noise fields, *J. acoust. Soc. Amer.* **28,** 3, 391–398, May 1956.

Author applies his general formalism [title source **28,** 1, 76–79, Jan. 1956] for predicting the motion of continuous systems excited by random noise fields to the special case of a finite string. Mathematical solutions are obtained for the following examples: (1) Brownian motion of the finite string; (2) response to spatially stepped, temporally delayed noise field; (3) response to turbulent flow along the string, which is either of finite length, or (4) infinite. Examples)2) and (3) are also investigated experimentally. In example (2) appears the capability of the string "remembering" or "forgetting" a signal received in the past, the "forgetting" effect being the larger the greater the damping.

R. Heller, USA

3790. Pietrasanta, A. C., Jet noise problem in aircraft carrier islands, *J. acoust. Soc. Amer.* **28,** 3, 427–433, May 1956.

Noise during jet aircraft launching operations seriously interferes with communications in important island spaces aboard aircraft carriers. Measurements of sound pressure levels made in these spaces during normal jet operations at sea are reported. It was found that these levels could be estimated from a knowledge of jet engine operating conditions, and the physical properties of the structures involved. The problem of the selection of criteria for speech communication is discussed. Noise reduction requirements for island spaces, based on estimated noise levels of present and future jet aircraft, are presented.

From author's summary

3791. **Pietrasanta, A. C., Noise measurements around some jet aircraft,** *J. acoust. Soc. Amer.* **28,** 3, 434-442, May 1956.

The noise fields around several jet aircraft have been measured for various engine operating conditions. Directivity patterns as a function of octave bands of frequency are presented. Acoustic power levels have been computed and found to agree with a previously published correlation of power level with engine operating conditions. Analysis of these data has led to the development of a procedure for estimating the characteristics of the noise fields around nonafterburner jet aircraft operating at military power.

From author's summary

3792. **Spandock, F., Acoustic standards** (in German), *Acustica* 5, 4, 197-207, 1955.

Two acoustic sources are developed as standards. One gives a constant static noise, that of spheres falling on a membrane; the other produces a sound pressure in an enclosed chamber from the driving of a highly-tuned oscillating plate as piston source. With the latter, a complete response curve can be covered. Examples of the constancy of the sources are given. The technique of the calibration and sources of error are discussed. For free-field calibration, the correction of the sound pressure for diffraction is measured by an electrostatic contrivance. Finally, certain aspects of the precision in practice of acoustical standardization are discussed.

From author's summary

3793. **Ewing, M., and Press, F., Rayleigh wave dispersion in the period range 10 to 500 seconds,** *Trans. Amer. geophys. Un.* **37,** 2, 213-215, Apr. 1956.

A composite Raleigh wave-dispersion curve obtained from earthquake seismograms is presented for the period range 10-500 sec. For periods greater than 75 sec, the dispersion is primarily influenced by the shear velocity gradient in the mantle. For periods less than 75 sec, the effect of the crustal layer is most important. Brief discussions of the spectrum of the initial impulse and stationary values of group velocity, as they influence the character of seismograms, are given.

From authors' summary

3794. **Moggi, G., The acoustical problem in heating and air-conditioning installations** (in Italian), *Termotecnica* **10,** 3, 109-118, Mar. 1956.

Author briefly states principles of acoustics, noise control, and vibration isolation. Noise problems associated with heating and air-conditioning apparatus are discussed in detail.

M. C. Junger, 7SA

Ballistics, Detonics (Explosions)

(See also Revs. 3662, 3770, 3782)

3795. **Stuhlinger, E., Control and power supply problems of instrumented satellites,** *Jet Propulsion* **26,** 5 (Part 1), 364-368, May 1956.

3796. **Krull, A. R., A history of the artificial satellite,** *Jet Propulsion* **26,** 5 (Part 1), 369-383, May 1956.

3797. **Lagow, H. E., Instrumenting unmanned satellites,** *Jet Propulsion* **26,** 6, 496-497 (Technical Notes), June 1956.

Soil Mechanics, Seepage

(See Revs. 3644, 3647)

Geophysics, Meteorology, Oceanography

(See also Revs. 3522, 3632, 3639, 3643, 3695, 3705, 3712)

3798. **Eckart, C., and Ferris, H. G., Equations of motion of the ocean and atmosphere,** *Rev. mod. Phys.* **28,** 1, 48-52, Jan. 1956.

The density of the air in the atmosphere, or of the water in the ocean, is a function of altitude or depth. Linear equations for the motion of such stratified fluids have been derived by many authors. Many have introduced simplifying assumptions into their derivations, with the result that it is difficult to compare one paper with another. The present review is a collection of the major systems of equations, in a uniform notation. The derivations given are those which bring out the interrelations of the various systems, and are sometimes quite different from those of the original papers. The solution of the equations is not discussed, so that the relative merits of the various systems cannot be evaluated.

From authors' summary by W. P. Elliott, USA

3799. **Sloan, R., Shaw, J. H., and Williams, D., Thermal radiation from the atmosphere,** *J. opt. Soc. Amer.* **46,** 7, 543-547, July 1956.

The influence of ground-level temperature and humidity on the intensity and spectral distribution of thermal radiation reaching ground level from the clear sky has been investigated in the spectral region between 4 μ and 15 μ. The influence of thickness of emitting layer or atmospheric path viewed by the detector was determined from measurements at various zenith distances. Empirical relations between atmospheric emission in various spectral bands and ground-level temperature and humidity are presented. Reviewer believes paper is a significant contribution to the quantitative determination of atmospheric radiation.

A. Whillier, South Africa

3800. **Klemperer, W. B., Recent research on standing wind waves** (in German), *Z. Flugwiss.* **4,** 5/6, 169-173, May/June 1956.

A brief account is given of recent research work aimed at theoretical clarification and practical flight exploration of the meteorological phenomena of the standing wind waves of orographic origin. In the course of these investigations soaring flights to unusual altitudes were made.

From author's summary

3801. **Sparger, C. R., A relationship between wind and heat change observed in a vertical column of the sea,** *Trans. Amer. geophys. Un.* **36,** 5, 775-778, Oct. 1955.

Few satisfactory conclusions have been reached as to the influence of the atmosphere on short-term heat changes in the sea. This paper reports a simple, empirical result in this regard, the rationalization of which may prove profitable. Direct comparison has been made of certain local heat changes observed in the sea and wind stresses computed from observed velocities. Data used are those gathered by ocean-station vessels occupying COCA (52° 45′ N, 35° 30′ W) during the autumn months of 1947 and 1948.

No apparent relationship existed between the local wind stress and the heat change occurring either within the mixed layer or, separately, below the mixed layer. But there seemed to be a connection between the cumulative effect of wind stress acting during one week and the total heat change in a 600-ft column of the sea the following week. For each year studied it was possible to find a direction such that the components of the individually observed winds in that direction varied in sign exactly as the heat change. The directions were different for the two years. A significant correlation was found to exist between the magnitude of the appropriate component of wind stress and the heat change, having taken the lag into account.

From author's summary

3802. Fritz, S., Scattering of solar energy by clouds of "large drops," *J. Meteor.* **11,** 4, 291-300, Aug. 1954.

For the case when absorption is negligible, direct and scattered solar beams have been followed down into clouds of "large" spherical waterdrops, to calculate the distribution of the generation of diffuse energy in the cloud. The generated diffuse energy is considered to obey a simple diffusion equation, from which the cloud albedo has been computed as a function of the cloud thickness, the mean free path, and the sun's zenith distance. One of the main results is the marked variation of albedo with zenith distance, especially for "thin" clouds. Results are compared with observations, and it appears that the dissipation of stratus clouds is often accompanied by a reduction in the effective scattering radius of the cloud drops. From author's summary

Lubrication; Bearings; Wear

(See Revs. 3490, 3516, 3627)

Marine Engineering Problems

(See Revs. 3518, 3676, 3712)

Letters to the Editor

3803. Concerning AMR 9, Rev. 2184 (July 1956): Shmakov, M. I., Utilization of gravel soils in earth dams.

The last sentence should read as follows: The permeability of the compacted dam material is rather *smaller* than the permeability in situ of the same soil.

The reviewer regrets this error.

L. Suklje, Yugoslavia

3804. Concerning AMR 9, Rev. 2546 (August 1956): Anonymous, Investigation of entrance flared in four directions.

The third line in the first sentence reads "...who must keep cross section as small as possible to avoid cavitation damage."

It should read "...who must, in one side, keep cross sections small, and, in the other side, avoid cavitation damage."

The reviewer regrets this omission.

E. O. Macagno, Argentina

3805. Rev. 1727 (June 1956): Volterra, E., A one-dimensional theory of wave propagation in elastic rods based on the "Method of internal constraints".

To my knowledge, my "Method of internal constraints" was never used by any of the authors quoted in the references of my paper, nor by anyone else. Perhaps the reviewer is unaware that, in a series of papers published as early as the thirties (the first paper having been presented at the International Congress of Mathematics in Zurich in 1932), I developed this "Method of internal constraints" (Elasticità-Vincolata) in order to study static deformations of curved and twisted bars. The papers were reviewed in various scientific journals of the time and nobody then challenged their originality. They have often been quoted in American and European papers and books (including **W. Prager, The general variational principle of the theory of structural stability,** *Quart. appl. Math.* **4,** p. 382, note 9, 1946; and **I. S. Sokolnikoff, Mathematical theory of elasticity,** *McGraw-Hill Book Co., Inc.*, p. 204, 1946).

Apparently the "number of misconceptions", which the reviewer wants clarified for him, pertain to the physical significance of my assumptions and to my mathematical development. A careful study of my previous paper, entitled **"The equations of motion for curved elastic bars deduced by the use of the 'Method of internal constraints'",** (*Ing.-Arch.* **23,** 6, 402-409, 1955) would clarify the reviewer's misconceptions. In fact, a whole paragraph of this paper is devoted to the explanation of the geometric significance of internal constraints imposed on the system. Moreover, in the case of flexural motions, the numerical computations and graphs presented in the reviewed paper show the main differences among the various theories. Although it is true that, for the special case of flexural waves, the Timoshenko solution gives closer results compared with the exact Pochhammer solution, these results are always dependent on the determination of the constant K (Timoshenko's shear coefficient), whereas in the "Method of internal constraints" the constant K does not intervene. More important, however, is the fact that the new method presented allows also the study of longitudinal and torsional waves.

It is not correct that, in the case of longitudinal motions, the "Method of internal constraints" does not present any essentially new theory. The frequency equation (equation 33 of the paper) has never to my knowledge been derived before. In fact, my method gives closer results in the problem of dispersion of longitudinal waves in infinite rods of rectangular cross section than the elementary, Love, and Bishop approximate theories; and, in the case of two-dimensional elasticity, my method gives results which are close to those of the exact theories given by Lord Rayleigh and Lamb. This is clearly shown in a recent report of mine under the title **"On the dispersion of longitudinal waves in elastic rods of rectangular cross section according to the one-dimensional theory of wave propagation based on the 'Method of internal constraints,'"** *Office of Ordnance Research, Jan. 1956, Tech. Rep.* 2.

Concerning reviewer's last paragraph, author invites the reviewer to support his strong remark that the paper is studded with wrong statements. The two examples which the reviewer presents as being wrong are, in fact, correct. Indeed, Professor R. M. Davies, in his well-known paper **"A critical study of the Hopkinson pressure bar"** [*Phil. Trans. roy. Soc. Lond.* (A) **240,** p. 452, 1948], states "The simplest theory of the flexural vibrations of a bar assumes that the displacement of an element of the bar consists solely of translation parallel to Oy" (the y axis in this case being the axis perpendicular to the x axis of my paper); and, on p. 453, "The larger root does not appear to have any physical significance under ordinary conditions of experiment (cf. Prescott 1942), and moreover the exact theory shows that c/c_0 is a single-valued function of a/λ; this root will therefore be ignored."

It is, moreover, very gratifying to the author to realize that, in the particular case of a bar of a circular cross section, his general results reduce to the particular results for compressional waves in two earlier papers by the reviewer and his senior co-author.

E. Volterra, USA

Books Received for Review

BLAIR, G. W. S., Measurements of mind and matter, New York, Philosophical Library, Inc., 1956, 114 pp. $4.50.

BLASCHKE, W., and MÜLLER, H. R., Ebene Kinematik. Mathematische Einzeleschriften Bd. 5., München, Verlag von R. Oldenbourg, 1956, 269 pp. DM 26.80.

CANNING, R. C., Electronic data processing for business and industry, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, x + 332 pp. $7.

CARMAN, P. C., Flow of gases through porous media, New York, Academic Press, Inc.; London, Butterworths' Scientific Publications, 1956, ix + 182 pp. $6.

CRANK, J., The mathematics of diffusion, New York, Oxford University Press, 1956, vi + 347 pp. $8.

FORBES, G. F., Digital differential analyzers, 3rd ed., Pacoima, Calif., George F. Forbes, (10117 Bartee Avenue), 1956, xii + 154 pp. + Appendixes. $7.50.

GRÖBNER, W., Matrizenrechnung. Mathematische Einzelschriften Bd. 4, München, Verlag von R. Oldenbourg, 1956, 249 pp.

HERMANN, R., Supersonic inlet diffusers and introduction to internal aerodynamics, Minneapolis, Minn., Leaside, Toronto, Ontario, Canada, Minneapolis-Honeywell Regulator Company, Ltd., 1956, xxi + 378 pp.

MANNING, G. C., The theory and technique of ship design, Cambridge, Mass., The Technology Press of the Massachusetts Institute of Technology; New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, x + 278 pp. $10.

NEWELL, H. E., Jr., Vector analysis (International series in pure and applied mathematics), New York, McGraw-Hill Book Company, Inc., 1955, xi + 216 pp. $5.50.

NEWELL, W. C., The casting of steel, New York, Pergamon Press, 1955, viii + 599 pp. L$\frac{0}{0}$ 5 5s.

OPPELT, W., Kleines Handbuch Technischer Regelvorgänge, 2nd ed., Weinheim, Verlag Chemie, 1956, 555 pp.

PERNOT, P., Introduction Au Calcul des Systemes Hyperstatiques, Paris, Gauthier-Villars, 1956, x + 398 pp.

PRIGOGINE, I., Introduction to thermodynamics of irreversible processes, Springfield, Ill., Charles C. Thomas, 1955, ix + 115 pp. $4.75.

Proceedings, American Society for Testing Materials, Vol. 55, 1955, Philadelphia, Pa., American Society for Testing Materials, 1956, xi + 1250 pp.

Proceedings of the Fourth Midwestern conference on fluid mechanics, Purdue University, Sept. 8-9, 1955. Lafayette, Inc., vii + 370 pp.

SCHULTZ, M. A., Control of nuclear reactors and power plants (McGraw-Hill series in nuclear engineering), New York, McGraw-Hill Book Company, Inc., 1955, viii + 313 pp. $7.50.

Symposium on Monte Carlo methods, Meyer, H. A., edited by, Univ. of Florida, Mar. 16, 17, 1954, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, xvi + 382 pp. $7.50.

TREYBAL, R. E., Mass-transfer operations (McGraw-Hill series in chemical engineering), New York, McGraw-Hill Book Company Inc., 1955, ix + 666 pp. $9.50.

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